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Statistically, travel by air is one of the safest forms of transportation. Yet we continue to experience aviation tragedies. Do we fully understand flight safety or is there another way of looking at the problem? In this work a new way of approaching the question of flight safety is developed, justified and illustrated. Traditional methods are shown to be insufficient for a full understanding of flight safety. They do not provide an adequate explanation of the *context* of aviation safety.

The issue is approached from a new perspective with a methodology based on a philosophical understanding of *explanation*. For the examination of the context of aviation safety traditional modes of scientific explanation are rejected in favor of a *paradigmatic* explanation. A framework for explaining the context of accidents and safety, in general, is synthesized from four broad paradigms which characterize its patterned nature: the cognitive paradigm, the paradigm of normal accidents, the paradigm of technology, and the paradigm of organizational complexes. The development of the framework is supported by a wide diversity of literature from philosophers, psychologists, social scientists and engineers. It is explicated with numerous examples throughout. The framework is then compared with the traditional mode of explanation through an extensive pedagogical case-study of a specific accident.

The new framework is complementary to traditional approaches and new insights are pointed up. Finally, some broad recommendations are made for the community of professionals concerned with improving aviation safety.

A Paradigmatic Framework
for Flight Safety

by

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Chapter 1

Introduction

2246:00[1] Seattle Center, MAC 4-0-6-4-1 is passing three-two thousand for one-five thousand[2]

2246:05 MAC 40641[3], Seattle Center, ident; fly heading one-five-zero vectors to McChord runway one-six in use, expect a P-A-R approach[4]

2248:52 MAC 40641 maintain one-seven thousand; expect lower in 30 miles

2248:59 Okay; stop at seventeen

2250:43 2-8-3-2-3 is level two-two-zero[5]

2250:49 28323, Seattle Center, ident[6]; expect a P-A-R approach on runway one-three

2252:18 Seattle, 641 is level seventeen

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1 Pacific Daylight Time in 24-hour designation (hhmm:ss).

2 These are transcripted quotes of actual radio communications between the aircraft and Air Traffic Control (ATC) controllers. Such communications are focused, brief and often cryptic. The identifier of the agency being called is stated first [*Seattle Center*]; the caller states his identifier next [*MAC 40641*]; and the message (information or request) follows. *MAC 40641* is the identifier of a C141 Starlifter, a large four engine jet transport in the United States Air Force's Military Airlift Command (MAC); *40641* is the "tail number" or aircraft serial number of this specific airplane. In radio communications involving numbers, the numbers are (should be) spoken digit-by-digit; e.g. 40641 is spoken *four-zero-six-four-one*.

3 This particular airplane is returning to its home base, McChord Air Force Base (AFB) near Tacoma, Washington, from Yokota Air Base near Tokyo, Japan.

4 Precision approach.

5 V 28323 is a Navy A-6 heading north enroute to Whidbey Island Naval Air Station (NAS). During this period the air "traffic" load was very light; the only other traffic for this controller's section included two commercial flights (radio communications not included here). Also note that the radio communications in the above transcript are picked up "in progress".

6 "Ident" means for the pilot to press a button on his transponder or "squawk box" (already set to a specified code) which will cause the coded aircraft blip on the ATC controller's radar screen to become bright for a moment, thus enabling positive identification of the airplane and its position.

2252:22 MAC 641, roger[7]; now cleared to one-zero thousand and uh left to one-five-zero

2252:28 One-zero thousand; left to one-five-zero; four-one

2253:09 Navy 28323 fly heading three-one-zero vector for uh runway one-three

2253:15 Three-two-three; three-one-zero[8]

2253:22 And Navy 323 is cleared to one-zero thousand, descend at your discretion

2253:26 Roger we're out of two-two-zero for one-zero thousand at this time

2256:16 And Seattle, 40641 is level at ten

2256:19 40641 maintain five thousand[9]

2256:25 Five thousand; 40641 is out of ten

This routine series of air-traffic-control transmissions [1] on March 20, 1975, resulted in the following press release from the Federal Aviation Administration (FAA) on March 24, 1975:

> "The crash of an Air Force C-141 jet transport on March 20, appears to have been caused by human error by an air traffic controller who inadvertently radioed descend instructions to the Air Force airplane instead of a Navy aircraft he was also controlling. ...Both aircraft were at 10,000 feet about 60 miles apart, with the Air Force airplane heading South and the Navy heading North. The controller identified the Navy A-6 on his radar scope and wanted to instruct it to descend to 5,000 feet, but instead of calling "Navy 8323" he radioed "MAC 0641". Then, soon after, the controller realized the error, but the C-141 had already disappeared from the radar scope and had crashed in the Olympic Mountains, where the terrain raises as high as 7,900 feet." ..."The FAA operates 20 Air Route Traffic Control Centers in the continental U.S. and in 1974 they handled more than 23 million aircraft operations." [2]

In the midst of clouds and dark night, the C-141 hit the 7150 ft level of a 7300 ft ridge in the rugged Olympic Mountains of Washington, instantly killing all ten crew members and the six passengers. The impact occurred at about 2258 PDT, approximately one and a half minutes after their last transmission cited above. We pick up the next transmission made by the Navy plane.

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7 "Roger" means "transmission received and understood."

8 In acknowledgements, after radio contact has been well established, communication tends to become very cryptic. Although not without its problems, in this light traffic case the identity is always clear from the rapid sequential response and (cryptic) identifier in the transmission.

9 The implied command is to "[descend and] maintain five thousand."

2258:35 Seattle Center, 28323 level ten thousand

2258:40 28323 level at five?

2258:43 Negative; level one-zero thousand

2258:46 28323 cleared to five thousand

2259:29 Whidbey Approach, Sector 3 handoff[10]

2259:34 Go ahead

2259:35 Navy 28323 descending to five thousand, uh bearing zero-two-zero at uh twenty miles

2259:41 Radar contact; he released?

2259:43 And he is released, descending to five

2259:55 28323 contact Whidbey Approach Control two-seven-two point eight [Seattle D3 releasing the Navy flight]

2300:01 2-7-2-8, thank you

2300:03 Go ahead [D3 in response to a call from D2]

2300:04 Yeh, this is two, where is MAC 40641?

2300:08 Ah shoot, I forgot to ship him to you; standby

2300:10 Where is he though?

2300:13 MAC 40641, Seattle

2300:19 MAC 40641, Seattle

2300:23 Good question, I saw him uh one fifty heading down by Bremerton

2300:31 MAC 40641, Seattle

2300:48 MAC 40641, Seattle[11]

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10 Radio communications transcribed here also include controller-to-controller communication. The controller referred to above by the pilots as "Seattle Center" is the Seattle Sector D3 controller. He is contacting the Whidbey Approach (Navy) controller; Seattle Sector D2 controller, covering the sector immediately south of D3, comes in shortly.

11 At this point other Sectors and civilian aircraft in the area were also trying to raise 40641 on the designated communication frequency that D3 was using. In the next transmission, "guard" frequency is the emergency frequency always in monitor mode on every radio. Also, at this time the assistant chief on duty was notified.

2300:54 MAC 40641, Seattle Center on guard

2301:25 That big area precipitation just southeast of Lofall, south-southeast [Seattle Departure (SEA TWR) at the SEA-TAC airport also trying to help find him]

2301:28 MAC 40641, Seattle

2301:36 I see somebody about uh 20 north of Lofall, ten seven [17,000] descending [SEA TWR with a radar sighting]

2301:38 MAC 40641, Seattle

2301:54 MAC 40641, Seattle

2301:59 MAC 40641, Seattle

2302:54 Departure where is that Saturn? [D3 talking to SEA TWR]

2302:57 Saturn is uh 20 make it 18 miles north-northwest of Seattle; will be above the traffic that's 10 north of Lofall

2303:05 That's the MAC coming to nine; is he going to be above him alright? [D3 is confused by a Northwest Airlines flight]

2303:07 Yes

2303:32 Radar contact on the MAC; you said he was above the Northwest? [SEA TWR]

2303:34 Saturn 10 is east of uh Lofall and he'll be heading to intercept above [SEA TWR]

2303:37 Thank you

2304:30 MAC 40641, Seattle...

At this point, aircraft accident preliminary notification procedures were initiated by the assistant chief. Contrary to the FAA release quoted above, it wasn't until about an hour later, after reviewing the taped transmissions, that it was realized that a wrong clearance was given. [3] The controller never knew he made the mental slip until then.

Introducing this work with a vivid account of this specific gruesome accident serves several purposes. First, it brings a sort of "behind the scene" reality to an aviation disaster *as it happens*; for most of us these things are experienced only through summary news accounts. Secondly, it illustrates the potential for accidents even under seemingly favorable environmental conditions (light traffic, no severe weather, etc.).

Thirdly, the cause seems to be "readily apparent" as the controller simply gave the wrong instructions to the MAC flight; an obvious "mental slip."[4] And finally, as a former USAF C-141 Navigator stationed at McChord AFB, this particular tragedy is especially significant to me. With 2500 hours of flying time, I have flown that particular mission from Japan to McChord, and the same approach over the Olympics, more times than I care to remember. I was also in the same squadron as the ill-fated crew (8th Military Airlift Squadron), though I separated from the service in 1972. In fact, I had flown that particular "tail-number" (airplane) itself.

Beyond these reasons, however, lies a *context* for this accident as well as other accidents. As I develop this thesis, the contextual richness will be examined in detail because, as I will show, there is much more to this accident than a "mental slip" by the controller. It will serve as a concrete example for the general flight safety framework that will be developed to help us understand the context of aviation safety.

The Problem of Flight Safety and Technology

Two recent reports by the Air Transport Association (ATA) and the Federal Aviation Administration (FAA) focus attention on the human elements of commercial aviation safety. As more advanced technology is considered for incorporation into the National Airspace System, the nature of human factors issues in aviation is evolving and receiving new emphasis due to the increasing use of automation and the future potential of artificial intelligence, system complexity and shifting roles for humans in the cockpit and air traffic control centers. [5] In the past, the FAA report notes, the development and application of new aviation system technology in ATC and flight systems has been primarily focused on increasing traffic capacity of the National Airspace System and economic efficiency of aircraft operation instead of flight safety. The current joint industry-government programs are focusing directly on human factors and aviation safety.

From a human factors perspective, technologically driven automation has had mixed blessings to this point. [6] Problems associated with computers in the flight environment, such as increased "head-down" programming time to modify flight plans, etc., have not been adequately addressed. A guiding framework for system design and evaluation has yet to be nailed down. Wiener summarizes the situation with the statement that: "The rapid pace of introduction of computer-based devices into the cockpit has outstripped the ability of designers, pilots, and operators to formulate an overall strategy for their use and implementation. The human factors profession is struggling to catch up." [7]

Another major problem is that the cockpit and ground-based technology is not being properly integrated. The air and ground environments have, for the most part, been treated as separate entities. [8] Even with today's modern "glass cockpit" aircraft the ATC system is not designed to tap the capabilities of their sophisticated modes of flight.

Lack of goal congruency can be a major factor affecting flight safety. All too often subsystems simply assume some shared tacit knowledge of the desired goal. Many ground and air systems now just contain information on state variables with no knowledge of goals or intentions. Earl Wiener calls for a new "guiding philosophy of automation" and notes, as part of that philosophy, that in real-time flight systems the current capability of sharing goals among system elements is "noticeably and perhaps dangerously lacking in most present day automatic systems in aviation and elsewhere." [9] Sexton emphasizes that mission scenarios need to be "the basis for all design activities and the benchmark against which the design is measured." [10] Operator intent inferencing is also an area receiving considerable emphasis in research on intelligent operator support systems, however, its efficacy is yet dubious. [11]

But this notion of goal congruency must be considered in its broadest context as well. Not only should the proper development and introduction of technological systems, subsystems or components require consistent purpose, design, and evaluation criteria; it should encompass an explicit contextual awareness of the operating environment. This means an extension of traditional human factors thinking, which has primarily focused on human-machine interactions, to include socio-technical and societal perspectives as well. Are organizational and societal implications given appropriate consideration in system design and implementation and in accident investigations?

Consider, for example, broad goal congruency issues such as the public's desire for flight safety and increased jet travel and overnight cargo *as well as* a desire for peace and quiet. A recent front page article in the Sunday Seattle Times [12] on a local controversy quotes a 1989 report by the federal General Accounting Office that "aircraft noise has become a significant national issue that threatens the continued growth of airports and their ability to serve the growing demands of the air-transportation industry." The GAO report criticizes the FAA for failing to anticipate this issue accross the nation including recent East Coast changes. It also doubted FAA's ability to study noise impacts: "We have reservations as to whether the FAA has processes in place to make reasonable judgment about whether airspace change will generate controversy and noise impact." It is simply not a goal of the FAA.

To pursue this example a bit further, production efficiency (reduced delays in arrivals, for example) has been the priority for the FAA, as was mentioned earlier. The proposed new plan to change arrival and departure patterns at SEATAC to help bring in more airplanes per hour and to help balance air traffic controller workloads will increase noise, however, and this has caused an uproar in the Seattle community whose Port Authority has been trying since 1985 to find a way to reduce the noise. From the perspective of the FAA's Northwest Mountain Region manager all one has to do to see the need for the plan is visit SEATAC's radar room. "My job is to safely and expediciously move airplanes," he says. Even safety is not the focus of the proposed changes. Increasing the separation between planes always is good for safety, but safety is not a stated goal of the FAA changes. It is not a point the manager stresses because statistics kept by the agency show year by year overall improvement in safety measures. From the perspective of the citizens on the Port of Seattle jet-overflights committee the decision process has left them feeling betrayed. Two years ago, rather than file a lawsuit over existing noise, citizen groups had agreed to join a noise-mediation group made up of industry, the FAA and community groups, whose goal was to "mitigate and/or reduce noise." Now they are faced with a proposal that focuses on other goals resulting in further increases in noise. One citizen commented that the mediation process has been no more than a "public relations bone thrown to quiet us down while the port and the airlines brought in more flights." Indeed, the FAA regional administrator said he is willing to "give the public a say," but made it clear that the FAA has authority to do what it wants and that it is his decision alone. "Technically, we're not required to have this blessed by anyone," he said. The newspaper article commented that "it was a vivid display of the singular power that the FAA has over the aviation industry and airport neighbors." All this controversy and conflict in a community whose very economic health is dominated by the company that makes most of the world's commercial airplanes!

Seattle is not unique in issues like this. A recent *Aviation Week* article notes that revival of plans for new runways at O'Hare International Airport in Chicago "has provoked suburban civic leaders to renew their fight against any expansion of the airport." [13] Goal congruency must be an issue addressed in any decision process involving potential impacts on flight safety. But, as I will show in later chapters, stated goals are not really what drives organizational complexes anyway. Even apparent congruency on formal goals and policies with respect to flight safety can end up as nothing more than window dressing over organizational reality.

Research Focus

This work seeks to develop a more comprehensive macro-level explanation of flight safety. The focus of the research is perhaps best characterized by the following hypothesis, stated in the null sense:

> **NULL HYPOTHESIS: Conventional explanations of flight safety and aviation disasters, as well as traditional human factors approaches to improve flight safety, are fundamentally comprehensive and complete; in that, given the honest and diligent efforts of experienced, well trained, and highly skilled aviation administrators and technical experts such as accident investigators, scientists and engineers following well established scientific methodologies, a full understanding of flight safety is achieved leaving unconsidered no important conditions which might undermine flight safety and contribute to accidents.**

In other words, current thinking, approaches and explanations work well enough to lead us to any improvements that can be gained. My objective is to refute this hypothesis in the following fashion:

First, the standard for conventional explanation of flight safety is the scientific method which seeks to explain accidents in a rigorous fashion, for example, through a logical chain of proximate "cause-and-effect" reasoning. It is given that this approach should not be the "baby to be thrown out with the bath water" -- I concur that it is necessary; but I am claiming that it is not sufficient. I will develop a paradigmatic explanation of flight safety which will be based on characteristic paradigms of cognition, technology and large-scale socio-technical complexes that have been developed and described in the published literature and applied in a variety of situations. I will argue through this alternative explanatory approach that a fundamental and important *context* for flight safety exists which tends to undermine safety and contribute to accidents, in effect, "setting up" the "operators" of the system (e.g. air crews and controllers) with increased chance of failure. And further, that these inherent system characteristics cannot be seen or addressed in any comprehensive sense through conventional accident investigation procedures or human factors engineering approaches which focus on specific and proximal causes and effects in the "apodeictic" sense discussed in Chapter 2.

The hypothesis will also be refuted with a thorough examination of a specific aviation accident which illustrates the thorough conventional investigation approach as well as questions and issues that go begging, issues which can be raised and addressed only from consideration and understanding of the paradigmatic context. Accident data, of course, is problematic in two well known senses. First, no matter how objective an investigator intends to be, whatever he or she observes, records, interpretes and reports is in large part determined by his or her "mental model" from which the situation gets viewed and the problems and questions get framed. Thus, data and/or relationships relevant to the paradigmatic context are likely not to be contained in an accident or safety investigation report. Secondly, the rarity of physical disasters and system adjustments precipitated by the ones that do occur preclude any meaningful statistical analysis. Nonetheless, I believe I can illustrate my points convincingly through an in-depth examination of the particular accident that introduced this topic -- MAC flight 40641. In addition, I will use published accounts and analyses by other authors of safety related accidents and issues in general to support my arguments.

Finally, I will draw upon trends in current aviation safety management and research that, although providing many new and noteworthy developments, illustrate a continued focus on conventional explanations and technological fixes for flight safety problems without addressing the paradigmatic context.

The understanding of failures (e.g. aviation safety related incidents or accidents) should reflect upon which goals and policies were contextually relevant and were in conflict or not achieved, or if in fact the goals and policies were appropriate in the first place or had evolved into something different over time or new goals surfaced (goal emergence). Relevancy of policy needs to be viewed from multiple perspectives, as was obvious in the proposed route change example above. The working hypothesis is that a lack of goal/policy-congruency which can manifest itself through adaptive changes in organizational complexes represents significant opportunities to address flight safety. Awareness of goal incongruity can focus attention on broad issues and higher level management decisions which may be precursors to the breakdown of complex systems in patterned ways that unwittingly erode safety. The incongruity might be intentionally or unintentionally structured; or it may be merely an apparent lack of congruence due to cognitive limitations and/or ineffective or inefficient communication, understanding or awareness of goals and policies among the pertinent systems, subsystems and system elements (human and machine).

To summarize this introduction, it is my conviction that a fundamental change in thinking about flight safety is needed. We need to reexamine how we *explain* flight safety. We need to rethink the basic assumptions and patterns that have evolved which characterize the way we tend to approach such things as accident investigations and aviation system design. The objective is to develop, justify and demonstrate a new approach for understanding the broader context of aviation safety.

Chapter 2

Methodological Theme: Paradigmatic Insight

My concern in this chapter is to build an appropriate methodological foundation which will help us ferret out and address some of the issues raised in Chapter 1. I will show that quite a different tack is needed than that of the traditional scientific method. This will be a "qualitative" examination of flight safety, which some would take as an immediate indictment -- especially those in scientific, engineering and management science fields who from their frame of reference tend to categorize "quantitative" with such virtues as "validity" and "rigor" and, by implication, "non-quantitative" with "non-valid" or "non-rigorous."

My intention in rejecting a quantitative approach for this investigation should not be taken as a general indictment of that approach. My professional background fits the model of traditional "quantitative rigor." Conventional quantitative studies are an integral part of the majority of scientific, engineering and systems investigations and obviously we would have obtained little knowledge without them. My concern is more with the scope of such methods, the mental framework which they impose, and their appropriateness for the problem at hand. It is an unfortunate fact of life that academicians and other professionals seem to settle into one camp or the other as proponents or opponents of quantitative or qualitative methodologies. Amongst the professional circles and communities within which I have worked -- amongst those who view the world almost solely through "quantitative lenses" -- there seems to be a sense almost as if a [properly performed] quantitative study is blessed with orthodox "holy water," whereas qualitative studies are forever tagged with the stigma of "impiousness," at best, or total hogwash at worst.

But the world can be viewed from many perspectives and those who stick religiously to one view or the other forgo a great deal of insight from approaches which advance an understanding of phenomena in other ways. We have no idea what new insights can be gained until we try on a different set of glasses. One can be precise and thorough in development of an explanation even where traditional "mathematical" approaches are inappropriate or misleading, or at best do not shed sufficient light on the problem at hand. What is important is not "quantification" but disciplined critical inquiry.

The footing we will stand on builds around a discussion that focuses on a philosophical understanding of *explanation* since our concern is with a more comprehensive *understanding* of flight safety. After a general discussion and defense of the approach, we will examine in some detail what it means to "explain" something. A critique of scientific explanation is presented and then contrasted against an alternative form of explanation -- paradigmatic explanation. The chapter concludes with a discussion of the confusion and controversy surrounding the term "paradigm[12]."

Approach

What makes this research unique is a different philosophical approach to understanding flight safety. *Explanation* is looked at in a different light than most of the human factors studies. Our perspective on flight safety is also broadened by building understanding through an integrating framework of existing philosophical paradigms. The objective is broader insight through a more generalized and unifying framework -- one which includes fundamental philosophical and sociological perspectives on complex socio-technical systems (such as the commercial aviation system).

Arnold Reisman has challenged the management and social science communities to do more of this type of "high-risk/big-leap" research which is unifying in nature [14] and he has examined a number of alternative strategies to accomplish it. [15] Generalization, unification and structuring research is more risky professionally than what he labels the other end of the research spectrum, the "ripple" or incremental

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12 The term "paradigm" has more than one connotation (although related) which will become clear as we proceed. Its usage in the title to this chapter invokes the connotation of its original meaning -- a "pattern" which can be pointed out and also a concrete example which illustrates the pattern particularly well -- which is the sense used by Albert Borgmann, discussed later in the chapter; it is this sense of the term that is then used thematically throughout the rest of this work. Whereas, in the context of the early sections of this chapter, and the literature cited therein, we see a common use of the term -- "bodies of knowledge" or the collection of global commitments, beliefs, models, assumptions, etc. shared by a scientific community -- which has resulted from pervasive confusion and misunderstanding of Thomas Kuhn's famous book, *The Structure of Scientific Revolutions*; a confusion which Kuhn's own ambiguous use of the term in fact precipitated. In this chapter the use of the term should be clear from the context of the discussion; however, we will address the confusion and controversy surrounding this important term in some detail later in this chapter.

approach, which is the most common way in which research is done these days. Under the ripple or incremental approach, incremental improvements are made on existing models and theories[13] [16] by, perhaps, expanding the dimensions of the same type of problem domain, or validating current theories which are often generated by logical deduction from *a priori* assumptions. Glasser and Strauss [17] endeavor to direct sociological research away from its preoccupation with this type of research. Reisman observes that, although "the incremental or the ripple process is probably one of the more difficult ways of getting a breakthrough of any significance[14] as it typically requires an extension of a well-developed body of theory" [18], it is the safest and most comfortable thing to do in an academic setting because "the incremental process is best understood by reviewers and editors of scientific journals and by university search, promotion, and/or tenure committees." Following the ripple process is "the surest way of securing a publication in today's flagship management science journals, which are basically by and for the academic community." [19]

The generalization/unification research is more risky and may "result in much criticism especially from those who are most comfortable with analysis as opposed to synthesis or design. 'So What?' types of reactions will be common." [20] David Bella, describes the *discipline* required of the members of a professional community by virtue of its social structure; for example, an implicit force to 'toe-the-line' in engineering.

> ...to have your peers affirm your work is highly rewarding. ...To depart from the paradigms of a community is risky because it increases the risk of being rejected by the community. ...Work which contradicts, or violates the paradigms is usually considered unreasonable, irresponsible, or inept. ...Thus, discipline is sustained through the expectations of peers. [21]

The generalized framework approach, as Reisman characterizes it, "typically does not require much computerization, if any, nor does it particularly get involved with the development and testing for effectiveness or for efficiency of any algorithms. It typically requires no data collection and validation is easily obtainable inasmuch as published works had served as the basis and the stepping-stones for the generalization." [22] With regard to a risk avoidance strategy, however, Reisman warns that, "if [operations research and management science] continue to inbreed in the incremental ways, we are doomed to extinction as a profession, ...buried in our own

13 Thomas Kuhn would call this "normal science" or "puzzle-solving."

14 Kuhn would call this "a paradigm shift."

models." [23] Bella sounds a similar warning that, although the disciplinary community's paradigms provide disciplined guidance and a framework of expectations for its members, thus helping to preserve the integrity of the community's body of knowledge and expertise,

> ...there is a danger, ...that members of disciplinary communities will come to believe that their only professional responsibility is to honestly perform work that meets the standards of the paradigms. That is, they will see their professional responsibility only in terms of performing their assignments and jobs in accordance with the accepted standards, the paradigms. This attitude assumes that the paradigms themselves are trustworthy. This assumption may or may not be valid. If the paradigms themselves become biased, then following such paradigms is not likely to evoke public trust. [24]

Bella also tags this notion directly to the university community in terms of a number of disturbing trends:

> First, obtaining outside funds is becoming a dominant activity of faculty. The university tradition of independent critical inquiry is sacrificed in order to meet the demands of outside funding sources. Graduate theses, which should be the most creative efforts of the very best students, become chores to be ground out to meet the needs of funding bureaucracies. Second, too often, students are learning to complete assignments through technique by rote rather than developing the ability for disciplined critical inquiry. Third, too often, education is seen merely as a preparation for an organizational position, a job. [25]

From another perspective, that of "futures research," Harold Linstone, in his preface to *Futures Research: New Directions*[15] [26], states that the significance of the collection of ideas and perspectives presented in the book derives

> ...from the fact that some twenty-three well-known workers[16] in this field have arrived at very similar conclusions from different interests and starting points, and differing experiences, in a variety of countries. They agree that we must move beyond the objective, analytic, reductionist, number-oriented, optimizing, and fail-safe approach to futures problems and learn to think with equal fluency in more subjective, synthesizing, holistic, qualitative, option increasing, and safe-fail ways. [27] ...[These] paradigms [first set above] of modern science and technology ...are still deeply and firmly entrenched. There is a very large community of believers developing methodologies and quantitative models. ...But there is a growing rumble of criticism, a realization that this may reflect an imbalance undesirable in dealing with futures problems. ...These concepts [second set above] are really "new" only in the framework of the dominant science-technology paradigms[17]. We may not have seen them before only because we were not looking for them and did not need them in the prevailing mode of problem solving. [28]

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15 This anthology grew out of an uneasiness, in Linstone's words, "about the state-of-the-systems approach in dealing with the complex behavioral-social-technological issues faced by planners." The issues are not just methodological but "challenges to long-accepted paradigms."

16 Including such "heavy-weights" in systems analysis, operations research and management/organizational science as: Richard Bellman, C. West Churchman, and Ian I. Mitroff.

17 The use of the term "paradigm" thus far reflects Kuhn's usage of the term to mean "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners." [*op. cit.*, p. viii] ..."works that serve for a time to implicitly define legitimate problems and methods of a research field for succeeding generations of practitioners" [p10] and by implication the shared beliefs, principles and background assumptions implicit in those works. [p10]

Elsewhere, Linstone recaps eight different works in a section entitled "New Insights About Complex Systems" and notes that: "All of these writers illustrate the search for new insights about system behavior without resorting to a representation or model simulating the physical system." [29] In fact, in a discussion on potential pitfalls of systems analysis, Majone cautions on the prudent use of interpretive tools:

> The danger of misuse of the formal tools of analysis is made particularly acute by the prevailing [paradigm], according to which the scientific character of a field is assumed to be in direct proportion to the degree of its mathematical or statistical formalization. In this perspective, quantification and algorithmic elegance almost become ends in themselves, not only at the cost of what cannot be easily quanitified but also at the expense of a deeper understanding of the substance of the problem.[30]

The underlying theme of my work is a broadening of perspectives on aviation safety. To this point it has been dominated by the traditional human factors and cognitive psychology perspectives; that is, the problems are defined in the context of the current human factors paradigms. This field is just recognizing the limitations of its underpinnings and practices. In a recent article Kenyon Greene writes: "Human factors research and application may be severely impaired through continued adherence to an obsolete paradigm." [31] The field has entirely overlooked the contextual aspects of human factors. It needs to be "much more congruent with the emerging new paradigm, with the *holistic* realities of complex systems, and with the concept of socio-technical work systems." [32]

In this work I seek a different way of explanation that will provide new insight. The work does not, however, seek cogency for some new "all-encompassing" framework which will address and solve all problems of aviation safety. Nor is the desire to subsume all other approaches under its umbrella. The intention is to provide additional illumination and insight that educators, policy makers, planners, decision makers, system designers, system users and the public can conceive of as a *context* for understanding and dealing with flight safety. Thus, the scope of questions and inquiries will be expanded which will have a positive impact on what constitutes acceptable guidelines and criteria developed by various agents for the management of aviation systems and the design and implementation of advanced technology in aviation systems.

The Importance of Explanation

The discourse that follows (and I will quote appropriately from some of the leading thinkers in this arena) may at first seem like an unnecessary diversion; however, limitations inherent in existing approaches to aviation safety make it necessary to consider an alternative approach. To reemphasize, the approach of this work is not "mainstream scientific methodology," thus we must understand upon what ground we are standing as we proceed with the development of our framework. As you read through the rest of this chapter, motivate your reading by keeping a concrete example in your mind of any aircraft accident and what it means currently in *your* mind to "explain" it. You will undoubtedly frame your thinking along the lines of cause-and-effect-chain reasoning.

Explanation is a difficult philosophical problem, but it is one we cannot duck if we are to disclose an alternative approach that will help us penetrate the contextual complexities of aviation safety. Stay with the development because understanding at least the essence of it is crucial to accepting the alternative approach for explaining aviation safety in general, and specific accidents in particular. The dominance of the scientific model of explanation must make room for an alternative but complementary approach because it fails us miserably in penetrating the complexities of the phenomena that constitute the contextual reality of aviation safety. You will see an explicit demonstration of the illuminating power of this alternative approach when I bring it to bear on the MAC 40641 accident in depth.

We begin with a bit of background on scientific thought, which until recently, has been dominated by a group referred to as "logical positivists" or, more recently, "logical empiricists." These are people of a school of thought, logical positivism (or logical empiricism) which Baruch Brody [33] describes as "the most important school in twentieth-century philosophy of science."

> This movement began in Austria and Germany in the 1920's, spread to England and America in the 1930's, and continues to have a great influence on the philosophical community in these countries. ...These logical positivists produced a powerful and persuasive conception of the scientific enterprise that has been adopted by many philosophers and scientists who do not [even] agree with the basic persuppositions of logical positivism. ...More recently, several younger philosophers of science have argued that the logical empiricist's view of science should be supplemented or supplanted. [34]

In his introductory discussion on the success of science, Joseph Pitt [35] describes the "hard times" the logical positivists have fallen upon in the past couple of decades. Pitt characterizes the positivists' problems from both logical and historical dimensions. The positivists held to stringent conditions that have been successively abandoned or modified as either too strong or not sufficient a requirement for knowledge; and, they held that scientific knowledge was cumulative, that is, a truly verifiable claim was true for all time. Verifiability (too strong a condition) gave way to confirmation, whose arbitrariness and insufficiency required invoking a "truth condition" in which knowledge was claimed to be "justified true belief." The concept of knowledge is still problematic.

> The development of the logical positivists' accord of scientific knowledge, evolved away from an older and very long tradition, in which knowledge means certainty, toward the newer view, associated with Humean empiricism, that knowledge is justified true belief. But the truth condition is just another way of asking for certainty. To truly differentiate between the two views we need to drop the truth condition. However, if we drop the truth condition and settle for justified belief, the fear is that this will reduce to straightforward belief. ...Even on those accounts which are alternatives to the positivists', the same problem emerges, for the issue of knowledge versus belief recurs. Once knowledge conceived of as certainty is abandoned for something cognitively less demanding, the issue of whether we ever really have knowledge is with us permanently. [36]

Opposition to the cumulative view of scientific knowledge was articulated most profoundly with Thomas Kuhn's *Structure of Scientific Revolutions* [37]; a work which, in Pitt's words, "contributed greatly to undermining the positivists' assumptions about the growth of knowledge." Kuhn conceptualized science as developing by revolutions, during which the basic assumptions and methods inherent in the universally recognized works of the community which have guided the science of the time (that is, the community *paradigm*) are abandoned in the face of mounting problems in favor of a new paradigm. Swept away with the old paradigm is all the knowledge it generated, since the new paradigm, by definition, uses new methods and assumptions which are incompatible with the old -- the history of science being the history of rejection of false theories.

This conclusion also seems too strong, perhaps, and Kuhn has had many critics [38]; however, Pitt notes that:

> Even if we reject Kuhn's account [of change-by-revolution] and settle for something less dramatic, ...we cannot help but observe the difference between theories we now use and those that were prominent a short while ago. It may be too strong to assert that the history of science is the history of the rejection of false theories, but something fairly close is not out of order. [Thus,] it does not look promising for the idea that the success of science can be cashed out in terms of increased knowledge. [39]

"The lack of philosophical success [in accounting for the success of science]," Pitt says, "may be a function of having asked the wrong questions." [paraphrasing] Instead of asking how the overwhelming presence of science in contemporary life has managed to increase our knowledge and foster technological growth, we should focus on *the nature of scientific explanation.*

> What is crucial is the insight that the kind of knowledge science produces, whatever form that knowledge takes, permits the development of explanations, and it is those explanations which are the real payoff. [40] ...It doesn't really matter what "knowledge" means. What matters is what counts as an explanation. By putting the emphasis on explanation we make it a criterion of adequacy for scientific progress. All the research in the world counts for nothing if it fails to generate explanations of the domain under investigation. [41]

The question then is: "What constitutes an explanation?" Pitt's anthology focuses on that question beginning with the logical positivist model (of Hempel and Oppenheim) that dominates our understanding of scientific explanation today.[18] We will see the relevance of this question in detail as we attempt a paradigmatic explanation of MAC flight 40641 later on.

Types of Explanation

In Albert Borgmann's [42] scholarly and rigorous development of a philosophy of technology [43], the issues of the relationship of technology to science, and what constitutes explanation, are of central importance in developing a clear and intelligent view of technology.[19] In what follows here, we will view the nature of the most dominant model of scientific explanation along with some of its criticism in Pitt's anthology as well as Borgmann's own critique. We will follow Borgmann's insightful structure, in which he categorizes and labels three types of explanation (apodeictic, deictic, and paradeictic explanation) on the basis of what each is intended to achieve and the scope of its relevance.

18 Pitt emphasizes that the problem of explanation is far from settled, but the importance of its central role in our still emerging understanding of science is unequivocal.

19 The flow of his early development in the introductory Part One, "The Problem of Technology," (the book has three parts), can be seen from the sequence of chapter titles: Technology and Theory, Theories of Technology, The Choice of a Theory, Scientific Theory, Scientific Explanation, The Scope of Scientific Explanation, Science and Technology.

1. Apodeictic Explanation

Borgmann points out that science, as the body of well-established laws and theories, is objective and cogent and indeed, it provides both the historical and contemporary standard for explanation; a standard which has gained its prominance predominantly through the physical sciences but has been emulated in virtually all other fields from biology to the social sciences.

> Our common understanding of the world is always -- and already -- scientific. More precisely, everyone takes a protoscientific view of the world. The objects around us, large and small, are seen *within the range of scientific explanation* [original emphasis]. Regardless of one's present competence or concern, most everyone admits that scientific scrutiny of any event or phenomenon is possible in principle; nothing falls beyond the scope of the sciences. [44]

The historical roots of scientific explanation relate to the notion of intelligibility and lawfulness, which Borgmann notes, goes back as far as Aristotle and, more recently, Kant. They would argue, Borgmann states, "that to render something intelligible is to place it explicitly in the matrix of laws and principles." [45] The logical foundation for this type of "covering-law" explanation is found in Hempel and Oppenheim's "Studies in the Logic of Explanation"[20][46] and further developed in Hempel's book [47].

Covering-Law Explanation

Hempel and Oppenheim begin with the statement: "To explain the phenomena in the world of our experience, to answer the question "Why?" rather than only the question "What?" is one of the foremost objectives of empirical science." [48] Their thesis is that "the *event* under discussion is explained by *subsuming it under general laws*, that is, by showing that it occurred in accordance with those laws, in virtue of the realization of certain specific antecedent conditions." [49] And, "the explanation of a *general regularity* consists in subsuming it under another, more comprehensive regularity, under a more general law." [50] (emphases added)

20 This paper Pitt describes as "the first major work on the topic [of what constitutes an explanation];" ..."the touchstone [paper] for the development of the topic in the contemporary literature." In the literature, however, it is Hempel who is cited as the key figure behind most of this thinking.

More formally, the basic pattern of scientific explanation has two major constituents, the "explanandum" and the "explanans." The *explanandum* is a sentence describing the phenomenon to be explained (not that phenomenon itself). The *explanans* is the class of those sentences which are adduced to account for the phenomenon. It has two subclasses: a set of sentences $C_1, C_2, \ldots, C_k$ which state specific antecedent or initial conditions; and a set of sentences $L_1, L_2, \ldots, L_r$ which represent general laws. For the explanation to be sound, its constituents have to satisfy certain conditions of adequacy -- logical and empirical conditions. These are:

R_1 The explanandum must be a logical consequence of the explanans -- deducible from the information contained in the explanans.

R_2 The explanans must contain general laws, which must actually be required for the derivation of the explanandum.

R_3 The explanans must have empirical content; that is, it must be capable, at least in principle, of test by experiment or observation.

R_4 The sentences constituting the explanans must be true -- satisfy some condition of factual correctness (this last condition characterizes a "correct" or "true" explanation, but may be disregarded when discussing the concept of potential explanation).

In schema form we have:

Explanans	$\left\{ \begin{array}{l} C_1, C_2, \ldots, C_k \\ L_1, L_2, \ldots, L_r \end{array} \right.$	Statements of antecedent conditions General laws
Logical Deduction	————————	
Explanandum	$\{$ E	Description of the empirical phenomenon to be explained

Consider an example given by Hempel and Oppenheim:

Question invoking an explanation response: Why does the mercury column in a thermometer temporarily drop and then rise swiftly when the thermometer is rapidly immersed in hot water?

Antecedent conditions:

C_1 Thermometer consists of a glass tube partly filled with mercury

C_2 It is immersed in hot water

General laws:

L_1 Laws of thermal conductivity: increase in termperature affects at first only the glass tube of the thermometer (in direct contact with water); by heat conduction, the rise in temperature later reaches the mercury (which also happens to be a better conductor of heat)

L_2 Laws of thermic expansion of mercury and glass: the glass expands and thus provides a larger space for the mercury inside, whose surface therefore drops; however, the coefficient of expansion is considerably higher for mercury than glass, and thus it expands more than the glass.

Explanandum:

E The mercury first drops, then rises rapidly.

Thus the event under discussion is explained by subsuming it under general laws, that is, by showing that it occurred in accordance with those laws in virtue of the realization of certain specified antecedent conditions.[21] To illustrate the explanation of general laws (as opposed to specific events), Hempel and Oppenheim give the example of explaining the validity of Galileo's law for the free fall of bodies near the earth's surface by deducing it from a more comprehensive set of laws, namely Newton's laws of motion and his law of gravitation, together with statements about particular facts, namely, about the mass and the radius of the earth.

As noted earlier, these kind of explanations are called "covering-law" explanations and their structure is referred to as *deductive-nomological* (or the D-N model) since it takes the form of a syllogism where a conclusion is deduced from premises that contain at least one empirical law (Greek *nòmos*). It is the logical form of a scientific explanation, as Borgmann notes, that gives it its cogent force. "If the laws and conditions are accepted as true and the rules of logical inference are followed, then the truth of the proposition that refers to the event to be explained cannot be refused." [51]

To highlight the *cogency* rather than the [D-N] *structure* of scientific or covering law explanations, Borgmann refers to them as *apodeictic*[22] explanations, from Aristotle's use of the Greek word *apodèixis* as a technical term for this kind of compelling demonstration. The use of this term focuses our attention on the type of explanation that science provides rather than its internal structure. We can then build a conceptual framework which allows for complementary kinds or types of explanation.

With respect to scope of applicability of covering-law explanations, Hempel and Oppenheim assert its applicability under both deterministic and statistical laws. A *causal explanation* they refer to as one variety of this deductive type, where the antecedent circumstances described in the sentences $C_1, C_2, ..., C_k$ may be said jointly

21 This thinking is the foundation of scientific explanation as we know it today, even though we may not always see it laid out in this format.

22 Pronounced *apo-dike-tick.*

to "cause" that event when the L_i imply certain empirical regularities. That is, when they assert general and unexceptional connections between specified characteristics of events, they are called causal, or deterministic, laws.

Statistical laws assert that in the long run, an explicitly stated percentage of all cases satisfying a given set of conditions are accompanied by an event of a certain kind. Although the emphasis of Hempel and Oppenheim's essay is on the deductive type of explanation, they assert that this type of explanation "has retained its significance in large segments of contemporary science," even in certain cases of scientific explanation that involve "subsumption" of explanandum under a set of laws of which at least some are statistical in character; where, perhaps a more adequate account calls for reference to statistical laws. [52] Hempel later [53] provides an account of *laws of probabilistic form*, in which the explanans imply the explanandum, not with "deductive certainty," but only with near-certainty or with high probability, an "inductive explanation". So the world of explanation and prediction, according to Hempel, consists entirely of deductive-nomological explanations and/or probabilistic explanations; both of which, however, are of the covering-law type.

Peter Railton [54] makes the case for a D-N-P (deductive-nomological-probabilistic) model when the mechanism responsible for the explanandum operates by chance, meaning it is a genuinely indeterministic process (such as α-decay)[23]. He argues that a D-N-P model can provide D-N probabilistic explanations which can "subsume a fact in the sense of giving a D-N account of the chance mechanism responsible for it, and showing that [the] theory implies the existence of some physical possibility, however small, that this [chance] mechanism will produce the [phenomenon that the] explanandum [refers to] in the circumstances given." [55] In fact, as an illustration of the ardent positivistic conviction Railton has for the D-N account (even more, it appears, than Hempel), he is not troubled with probabilities that must, out of pragmatic necessity, arise from "an unknown or uncontrolled scatter of initial conditions."

> If something does not happen by chance[24], it cannot be explained by chance. ...The use of statistical probabilities in connection with such phenomena unquestionably has instrumental value, and should not be given up. What must be given up is the idea that *explanations* can

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23 As opposed to probabilities which arise from an unknown or uncontrolled scatter of initial conditions, such as those associated with standard gambling devices, classical thermodynamics, actuarial tables, weather forecasting, etc.

24 See previous note.

> be based on probabilities that have no role in bringing the world's explananda[25] about, but serve only to describe deterministic phenomena. [56] ...The D-N-P model enables us to state quite simply the object of induction in explanation: given a particular fact, to find, and gather evidence for, an explanans that subsumes it; given a generalization, to find, and gather evidence for, a higher-level explanans that subsumes it; in all cases, then, to discover and establish a true and relevant explanans. The issue of showing the explanandum to have high (relative or absolute) probability is a red herring, distracting attention from the real issue: the truth or falsity, and applicability, of the laws and facts adduced in explanatory accounts. [57]

On the D-N model's relevance to explanation in the nonphysical sciences, Hempel and Oppenheim assert that, although in biology, psychology and the social sciences, "...[the] laws cannot be formulated at present with satisfactory precision and generality, and therefore, the suggested explanation is surely incomplete," explanation still attempts [paraphrasing] to account for the phenomenon by subsuming it under the laws and thus the logical structure of causal explanation is the same as in the physical sciences. [58]

> It is quite possible that most or all of the regularities which will be discovered as sociology develops will be of a statistical type... This issue does not affect, however, the main point we wish to make here, namely that in the social no less than the physical sciences, subsumption under general regularities is indispensable for the explanation and the theoretical understanding of any phenomenon. [59]

On teleological concerns, Hempel and Oppenheim acknowledge alternative opinions that causal explanation is essentially inadequate in fields where purposive behavior is a significant part of the phenomenon to be explained. Such an argument calls for reference to motivations and thus for teleological rather than causal analysis. "Thus, we have to refer to goals sought; and this, so the argument runs, introduces a type of explanation alien to the physical sciences." But, they counter argue that it is not that different from the causal explanations of the physical sciences, because "the determining motives and beliefs, ...have to be classified among the antecedent conditions of motivational explanation, and there is no formal difference on this account between motivational and causal explanation." [60]

Examples of D-N Explanation in Cognitive Psychology and Human Factors Studies

Above I have summarized the basic ideas behind the dominant D-N model of scientific explanation. The implicit application of this type of explanation in cognititive psychology can be seen in Glass and Holyoak's introduction to their book *Cognition* [61]. The present a very nice development of "reading" as an "excellent

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25 Plural of explanandum, i.e. the phenomena of the world to be explained.

example of human information processing, since it calls into play virtually every aspect of the cognitive processing that we will be exploring in this book." [62] Antecedent conditions and facts are discussed and a sequence of related laws (currently accepted as part of cognitive psychology's scientific paradigm) are presented that successively explain more and more of the phenomenon of reading. The desire is clearly to illustrate a reductionist, mechanistic explanation that subsumes (with admitted imprecision and incompleteness) the phenomenon, or process of reading, under currently understood regularities and laws.

> "Reading is so effortless, and we are unaware of so many steps in the process, that it is easy to overlook the complexity of the mechanism that makes it possible to be aware of the message *without* necessarily being aware of the individual sentences, words, or letters on the page. However, just because an activity seems easy to do does not mean that its underlying mechanism is simple. Consideration of all that must be involved in reading should give you some inkling of the complexity of the mechanism that drives human cognition." [63]

Althought the field of human factors engineering encompasses many areas, one of the things human factors engineers endeavor to do is to build mathematical models of humans and their interactions with machines [64] with the "goal [of developing] methods of analysis that allow one to *predict* performance." [65] ..."To predict the performance of a human-machine system, we require some representation of the system that allows us to determine how independent variables affect dependent variables." [66]

That is, antecedent (initial and parametric, e.g. reaction time) conditions are quantified, as are the regularities, laws and relationships [67] of human-machine behavior, in order to predict [explain through functional relationships at some level] the behavior of the human-machine system in terms of outputs of interest. The complexity of human beings is dealt with in the most convenient manner; but the attempt is, nonetheless, to explain the behavior of the system through the mathematical model of the human element even if that model is heuristic in the sense of a machine analogy. "For a variety of obvious reasons, it is appropriate to represent human behavior in machine-like terms." [68] However, Rouse does distinguish between the human's "behavior" (*what* the human does), and "performance" (*how well* it is done).

> Since a variety of patterns of behavior [for example, the specific time history of control movements] might result in the same performance [for example, the rms tracking error that results], it is very much easier to develop models to predict performance than it is to develop models to predict behavior. ...Since a model that can accurately predict behavior

> will also be able to accurately predict performance (but not vice versa), a behavioral model is much "stronger" in the sense that it more completely describes the human as he performs the task of interest. [69]

The need for new "machine analogies" (explanatory laws) for humans asserts itself, Rouse notes, due to the increasing use of automation.

> The increasing use of computers to perform control tasks has resulted in the human's role becoming more like that of a monitor and supervisor. In such a role, the human can have responsibility for more tasks. Furthermore, as a backup for the computer, the human has to help in detection and diagnosis of system failures. Viewing the human as monitor, supervisor, and diagnostician leads to three new analogies: ideal observer, time-shared computer, and logical problem solver. ...The logical problem solver analogy ...reflects a recognition of the importance of understanding the human's role in systems where the ultimate responsibility for system failure is the human's.[26] [70]

The point I am trying to make here is simply to illustrate that the focus of explaining human elements in systems is of the D-N covering law type, via modeling relationships based on machine analogies from which the human behavior or some resultant measure of it can be deduced. Given model **x**; here's the **y** that we can conclude. Among the many problem domains Rouse considers are aircraft piloting and air traffic control, however, "absolutely no attention is devoted to personality, motivation, etc." Hence, he acknowledges, "this book does not, by any means, address human behavior in the complete sense of the phrase. Nevertheless, the types of behavior considered are among the more important of those that can realistically be studied within engineering design."[27] [71] The modeling is focused on understanding human performance; the issue of safety is not addressed at all in either the development or application of these models (other than being mentioned on page 1, in recognition of its importance). The point here is not a critque of simplification in modeling, which everyone knows is necessary; it is that apodeictic explanation is still the predominant approach in trying to deal with the complexity of humans, and most of this complexity is impenetrable. So what other avenues do we have available to us for explanation?

Inadequacies of the "Scientific Explanation"

As noted earlier from Joseph Pitt's comments, the debate about explanation continues and is yet unsettled. [72] We will highlight some difficulties of scientific

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26 I will have much discussion on this later.

27 Thus the realm of acceptable problems is implicitly defined by the limitations of the dominant paradigm!

explanation, as articulated in Hempel and Oppenheim's covering-law account, which will lead us to the issue of what actually constitutes an explanation and some alternative perspectives on it. We approach this from two perspectives, the first is that of Michael Scriven who identifies several cracks in Hempel and Oppenheim's D-N account of explanation, hammers a good sized wedge into each, and outlines a new account of explanation and understanding. A second perspective is provided by Albert Borgmann who, while acknowledging the important role of "subsumption under the laws" in scientific explanation, elucidates gaps around the notion of scientific explanation, itself, and why "subsumption under the laws," although necessary for a full understanding of technology and its relationship to science, is by no means sufficient. The gaps he identifies provide another opening for us to reflect on our understanding of what it means to explain something. Borgmann presents alternative modes of explanation that fill these gaps.

Scriven attacks a series of analytical claims about the covering-law logic of explanation and points out what is lacking in them, or is too restrictive about them. I will only summarize his main points here, leaving it to the reader to review Scriven's article in detail for the full impact and justification of his critique. The claims he addresses are: explanations are answers to "why" questions; explanations are "more than" descriptions; explanations are "essentially similar" to predictions; explanations are sets of true statements; and there is a linguistic structure of explanations with the requirement of deducibility. The key points of his criticism of Hempel and Oppenheim's D-N model are [73]:

1. It fails to make the crucial logical distinction between explanations, grounds for explanations, predictions, things to be explained, and the description of these things.

2. It is too restrictive in that it excludes their own examples and almost every ordinary scientific one.

3. It is too inclusive and admits entirely nonexplanatory schema.

4. It requires an account of cause, law, and probability which are basically unsound.

5. It leaves out of account three notions that are in fact essential for an account of scientific explanation: context, judgment, and understanding.

Scriven's thesis is that the essence of explanation is a conveyance of an understanding of a phenomenon. Any information that can provide for an understanding is adequate for an explanation, whether or not it involves a law or theory. The challenge to an explanation should be based on the grounds for explanation: it may be argued that the information conveyed is false, that it has no bearing on the phenomenon being explained, or that it is not the sort of thing that is being looked for in this particular context. Laws or theories can be used as a defense against the second challenge, so they are possible (but not necessary) partial grounds for defending an explanation that has been challenged; but that is all they are.

An explanation must be capable of making clear something not previously clear, that is of increasing or producing understanding of something. "Explanation sometimes consists of simply giving the *right* description." [74] The appropriate piece of informing or describing is a matter of its relation to a *particular context*. It is those things that are not properly understood that we see as needing explanation in a given context.

As I indicated earlier, much of this paradigmatic framework development will consist of elucidating the appropriate context for a fuller understanding of flight safety.

Hempel and Oppenheim's analysis presupposes a linguistic structure for an explanation that Scriven rejects as unnecessary.

> It is the *understanding* which is the essential part of an explanation and the *language* which is a useful accessory for the process of communicating the understanding. By completely eliminating consideration of the step from the phenomenon to the description of the phenomenon, Hempel and Oppenheim make it much easier to convince us that deducibility is a criterion of explanation. [75] ...The most serious error of all those... in Hempel and Oppenheim's analysis ...is the requirement of deducibility itself, plausible only if we forget that our concern is fundamentally with a phenomenon, not a statement. [76]

"Deduction," Scriven argues, is "a dispensable and overrestrictive requirement which may of course sometimes be met." However, unexplained things can be "such that they are explained *merely* by being described in the correct way regardless of deduction from laws." [77]

> The point ...is that understanding is roughly the perception of relationships and hence may be conveyed by any process which locates the puzzling phenomenon in a system of relations. When we supply a law, we supply part of the system; but a description may enable us to supply a whole framework which we already understand, but of whose *relevance* we had been unaware. We deduce nothing; our understanding comes because we *see* the phenomenon for what it is, and are *in a position* to make other inferences from this realization.[28] [78]

With respect to confirmation, Scriven comments: "We must insist on making a distinction between a dubious explanation and one for which further confirmation -- in the technical sense -- is still possible: every empirical claim has the latter property." [79] Scriven provides a lucid example involving the explanation of the collapse of a

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28 This idea is central to the approach I will take in developing an explanatory framework for the context of flight safety.

bridge and the problem of direct versus indirect confirmation of the conditions that can explain its failure. "Direct confirmability when complex systems are involved," he states, may not be possible because "it is often impossible to specify what counts as the same conditions." Scriven's example and argument render Hempel and Oppenheim's notion ludicrous that a causal explanation can only be justified by direct test of the conditions from which the failure could be predicted (through its deducibility). Also, we know something when we are called on for an explanation of an event, such as the bridge (or aviation system) failure, that we don't know when we are called on for a prediction: namely, that the event referred to has already occurred! This is extremely useful information in understanding what happened, because it may illicit or demonstrate the existence or absence of a whole combination of conditions that, due to the system's complexity, we could not have understood or expected to occur, or perhaps interact in the way they did.[29]

In summary, Scriven's thesis of explanation is that it is inextricably linked to understanding, which is surely contextual in nature. In a given context, he emphasizes,

> ...certain kinds of data are taken as beyond question, and there is no meaning to the notion of explanation and justification which is not, directly or indirectly, dependent on a context. ...The request for an explanation presupposes that *something* is understood, and a complete answer is one that relates the object of inquiry to the realm of understanding in some comprehensible and appropriate way. What this way is varies from subject matter to subject matter ...and what counts as complete will vary from context to context with in a field. ...The concept of explanation is logically dependent on the concept of understanding, just as the concept of discovery is logically dependent on the concept of knowledge-at-a-particular time. One cannot discover what one already knows, nor what one never knows; nor can one explain what everyone or no one understands. These are tautologies of logical analysis. [80]

Borgmann fully acknowledges the significance of scientific explanation and with rich examples, such as the fermentation of wine, describes how modern science provides a more coherent and detailed view of the world. It renders perspicuous the seemingly opaque phenomena and processes of the everyday world. It allows us to see more precisely what a phenomenon consits of, connecting that phenomenon more definitely and more completely to other phenomena.

"Wine is an ancient drink and has had an important place and rank in the human world. Like many other things, wine began to be analyzed in terms of modern science with the rise of that science." [81] The scientific laws of chemistry tell us why grape

29 This is a very important notion I will use as the framework is developed.

juice turns into wine; "...when we so analyze fermentation, we have already taken the standpoint of *modern* science. From that point of view, fermentation appears as a manifold and complex process..." [82]

The positivists [Hempel and others] claim that any kind of explaining is valid only to the extent that it approximates the ideal of subsumption under laws. That is, this mode of explanation is not only necessary but sufficient for all phenomena demanding explanation. However, Borgmann questions this claimed *scope* of scientific explanation. In an article which explores philosophical issues of mind, body and reality, Borgmann writes:

> Assuming that explanation generates understanding, explanation and understanding span a systematic spectrum of ambiguity of which one extreme has been extolled to the detriment of the other. In Hempel's tradition to explain the world or a part of it is to subsume a particular event or regularity under law. This is the view of explanation and understanding that we have taken for granted so far. [83]

Elsewhere, in refering to the reductionist nature of scientific explanation, Borgmann writes:

> Science reveals detail because its theories ultimately treat of microparticles ...[which, for all the varied phenomena] discloses the many bonds of commonness among phenomena. This is the explanatory power of science: it explains everything more precisely and more generally than any prior mode of explanation. From this we should conclude that science can also provide a precise and general explanation of technology just as it has furnished one for fermentation. We know as a matter of fact that this has not been done. Is it to be expected? Is it a matter of principle or practical circumstances that a scientific explanation of technology has not been forthcoming? What is the scope of scientific explanation? [84]

Borgmann addresses some of the same issues that Scriven did. The problem of the "why" question -- there is no scientific answer to the request: "Explain the northern lights to me;" but, science can address questions such as: "Why do the northern lights pulsate?"; and, the problem of context -- "even when the explanandum has the required sentential form, it can be subsumed under very different laws because indefinitely many causal lines intersect at the place where an event is located in the nomological network, and so the event instantiates and is subsumable under many laws." [85] But even if these issues of ambiguity are resolved, the issue of sufficiency of the scientific mode of explanation is not resolved, and it is here that Borgmann opens up the gaps around *scientific explanation* itself. From science, we do not have a full account of what it means to explain something.

On one side, Borgmann points out that scientific explanation proceeds only when the scientific laws are given. "Even in the case where the laws are discovered in an attempt to solve a problem, the discovery itself, though it is part of an explanation, is not thereby explained. We have no general explanation of how scientific laws are discovered." [86] There appears to be no rule whose application leads to scientific discovery; thus scientific progress seems to be unpredictable in a strict sense and unexplainable by subsumption under any "laws" of progress.

> We cannot deny that in the development of science, theories supersede one another in attaining ever greater explanatory power. ...However, the power has not expanded to cover its own history and character. The result of the history of scientific progress does not explain itself in the deductive-nomological sense. ...*But the history does exhibit a pattern which can be pointed out.* [87] (emphasis added)

Thomas Kuhn's influential thoughts have provided a profound explanation of scientific progress by articulating its pattern -- not by subsuming it under any law or by predicting what, when, where, how or why the next breakthroughs will occur. He has given us an *understanding* of the changes in science and of scientific progress by pointing out its features and characteristics.

Borgmann points out a gap on the other side of scientific explanation; that is, "an explanation gets underway only when it is clear what problem is worthy and in need of explanation. But again we have no general explanation of how problems get stated." [88] A theory of what is worthy and in need of explanation does not come from modern science, which provides only a realm of possible worlds within the matrix of scientific laws; nor does it come from modern technology, which reflects a determination to act transformatively on these possibilities.

> Neither has a principled way of problem *stating*. ...Modern science cannot embody a substantive world view of a scientifically authenticated sort. [And,] ...technology, ...merely as the determination to transform, faces an indefinite number of transformative possibilities and cannot provide principled guidance to problems. [89] ...We can conclude then that the sciences reveal in a principled manner the general structure of reality and that the resulting insight is known to provide great transformative power. Scientific knowledge is a necessary condition of modern technology; it is not, however, sufficient. The question remains of how technology acts on the transformative possibilities provided by science, and the description of the character of technology is a task in its own right. [90]

> [Thus, apodeictic explanation] is limited in scope because in general it cannot disclose to us how it gets underway, i.e., how its laws are discovered and how something emerges as worthy or in need of explanation. But it is just the well-defined scope of these explanations and their perspicuity that force assent and give them cogency. In a scientific explanation it is entirely clear what in general (the laws) and in particular (the conditions) is the case and how the general and particular (the explanans) issue in a definite outcome (the explanandum). I cannot withhold assent and must declare: Yes, this is so. But the assent that is exacted by scientific cogency is as narrow as the explanation. Normally it ties me into the world by so thin or shallow a bond that I am not moved to act. It is only when a scientific explanation comes to be located at the center of a more profound concern that it can serve as a trigger for action. [91]

As noted earlier, the physical sciences have provided the dominant model for explanation and our established way of thinking by emphasizing antecedent and controlling conditions. But, as Borgmann points out, even though at higher levels of complexity as in mineralogy and biology things fall into natural kinds with their general properties and predictable patterns of behavior,

> ...it is at the level of human beings and human society that complexity becomes forbidding. ...[Although] humans are composed of physical particles arranged in particular ways which instantiate and constrain the laws of natural science, and human beings are part of nature and exhibit the regularities of a natural kind, ...[there is] resting on this orderly basis, a complexity in and between humans that allows no precise and penetrating summaries. Mainstream social science in this country has vigorously and vainly sought to discover laws of human society that would approximate in rigor and comprehensiveness those of the physical and biological sciences. [92]

Human factors engineering has long relied on isolated data, anecdotal evidence, operating experience and so forth. But human factors engineering and cognitive research surely aspire to this apodeictic orientation of the natural sciences. And it is not to say that little understanding has come from these fields. What I am saying here is that its dominance has predefined the way in which we structure our thinking, our questions and our problems, and the types of explanations we seek related to such phenomena as aviation disasters. [93] Human factors engineering concerns the design of equipment in accordance with the mental and physical characteristics of operators. But even solid efforts in these areas are often fraught with contextual difficulties which limits their influence and restricts their perspective. [94] Perrow gives a lucid argument explaining why military and industrial top management personnel have been indifferent to good human factors design and shows how the social structure favors the choice of technologies that centralize authority and deskill operators and how it encourages unwarranted attributions of operator error. David Bella provides a description and model of systematic distortion of information within organizations. He argues that organizations tend to distort information to meet organizational needs, not through dishonesty (necessarily) but as a systemic property of organizational systems themselves. [95] These phenomena are not considered as appropriate problems under the paradigms of human factors engineering and cognitive psychology.

In questioning the nature and amount of qualitative progress of "American-style" human factors work, Kenyon DeGreene writes:

> Certainly we have developed a large number of useful and important working principles. However, whether there has been equivalent progress in theory building and in understanding the macrolevel contextual factors that may encourage or constrain human factors work can be questioned. ...Without systemic theory and being in the right scientific paradigm at the right time, most human factors research and much applications work may be inappropriate, wrong, misleading, or counterproductive. Apparently new directions of effort (e.g., cognition, artificial intelligence/expert systems, and person-computer interaction) may be dead-end, last-ditch gasps of an exhausted paradigm. [96]

Greene notes that the rationalistic Newtonian paradigm that has profoundly influenced Western thinking for several hundred years, has dominated American thinking in the behavioral and social sciences with great expansion occurring throughout this century. It is this scientific paradigm and its legacy which characteristically...

> ...involves analysis and reduction and the identification of parts and the causal connections between parts as the means of system understanding ...deals with reversible situations, systems that preserve structures and functions in uniform environments, equilibrium-seeking behavior, and deterministic causality...deals with the most typical or average system elements or cases and with the most probable events...is highly rationalistic and emphasizes objective observation and the detachment of the observer from the observed system ...is not applicable to far-from-equilibrium conditions; evolving systems; the microdiversity of systems; fluctuations of system elements, variables, parameters, and environmental conditions; and systems undergoing structural change. [97]

Greene is concerned about the future of human factors research and concludes emphatically that it is time for a change:

> ...the scientific and social paradigms that have guided and shaped human factors work should now be thoroughly reevaluated. These go back 100 years with little change. ...The legacy of behaviorism in particular should be rejected, ...[and] human factors should reject the "machine model of man." [98]

Indeed, throughout even the broad category of the social sciences, researchers have attempted to emulate this apodeictic orientation of the natural sciences. Hoos provides a scathing dissection of systems analysis as applied in the social context. A key implication of her analysis is that simple, logical ("rational") techniques are immensely appealing and intellectually arguable but their very simplicity ignores political, ethical, and computational constraints. [99]

How then can we *explain* a "world view," for example, or a concrete "thing or event of significance in its own right?" What are the alternatives for understanding phenomena in the social realm?

2. Deictic Explanation

"To articulate something," Borgmann points out, is "to outline and highlight the crucial features of something" and this "is also a kind of explanation" that *can* satisfy such a request posed above. Scriven would surely agree. Borgmann calls this *deictic*[30] explanation to distinguish it from deductive-nomological or subsumptive explanation. [100]

Early scientific theories of the Western world (Aristotle, for example) had both world-articulating and world-explaining (in the subsumptive sense) significance. Aristotle's science and laws were moored in an articulated world order, pointed out in his vision of the world from metaphysical, ethical and other viewpoints. However, the progress of science, Borgmann continues, marked by improvements in the scope, precision, and consistency of the laws, has gained ever greater explanatory power in the deductive-nomological sense. In the process, the laws have lost their power of world articulation. "This is not a failure of science. Nor is it the case that the *deictic* achievement of the earlier sciences was ...unique," for art and poetry have always [paraphrasing] been supreme deictic disciplines, gathering, guarding and presenting something of ultimate significance. [101]

To explain is to generate understanding and it has senses other than the subsumptive sense of scientific explanation.

> To help someone to understand a painting or a valley in the wilderness is to point out, to make present in its crucial features. Such explanation does not consist in simply inviting questions that are to be answered in the subsumptive mode because such questions are frequently misdirected and unhelpful... [We are talking about] a common and crucial sense of 'explaining'. One may call it "acquainting" or "deictic explaining" to distinguish it from explaining in the subsumptive sense. [102]

The word "deictic" comes from Greek *deiknýnai*, meaning "to show, to point out, to bring to light, to set before one, and then also to explain and to teach." [103] This "language of ultimate concern" has many other forms as well as art and poetry. It is a language that reaches out to its listeners and through enthusiasm it has the force of testimony and through sympathy and tolerance it has the force of appeal. Borgmann teaches us its power as we see his use of it in his extensive discussions of focal concerns and focal things in order "to speak in a principled and forceful way" about these things which exhibit significance in their own right (a festive meal, for example, or a wil-

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30 Pronounced *dike-tick.*

derness experience). These are things whose essence is best explained and understood through deictic discourse. This mode of explanation Borgmann views so important in addressing the question of the good life that he devotes a 13 page chapter titled "Deictic Discourse" to "the elaboration of deictic speaking, of the attitude it embodies and the force it possesses, its connection with democracy, and its complementary relation to apodeictic and paradeictic explanation." [104] Deictic discourse, however,

> ...does not strive after cogency since it cannot, nor does it wish to, control its subject matter. But neither is it arbitrary since it is guided by an eminent, publicly accessible, and tangible concern which can be pointed up and explained. [105] ...Discourse of ultimate concern can draw continued strength from something that is present visibly, forcefully, and in its own right, and it can address others by inviting them to see for themselves. [106]

How do we explain our *concern* with aviation safety, for example? The concern with safety for oneself and their loved ones from life threatening tragedies (such as an aviation disaster, for example) and the bonds that humans feel for their fellow beings, cannot be more vividly brought home than through deictic discourse. As gruesome details are set before the community in written, spoken and visual accounts of the scene; as the shock and sorrow is expressed by those closely involved; as the tragedy is *explained* to us in deictic language, we are saddened; we feel moved with sympathy and frustrated in our inability to understand why such disasters continue to occur. And we feel a sense of powerlessness as individuals to prevent their occurrence. Many of us are moved to make personal decisions to modify (at least temporarily) our lives in some sense by changing schedules, routes, airlines, types of airplanes, or in fact deciding not to fly at all.

The horror of a "Lockerbie"[31] as the vivid details are described and explained to the world, is no less experienced than when a senseless accident of more local concern, such as MAC 40641, strikes a community like Tacoma, Washington. A community whose citizens see the huge, lumbering jets overfly the town taking off and landing at McChord AFB many times a day. A community whose sons and daughters, husbands and wives, friends and acquaintances feel some sort of direct or indirect contact and closeness with the people of McChord and thus share in the loss. People are moved in demanding to know how this tragedy can happen; newspapers are moved to investigate, point out and bring to light, not only the facts and details but the feelings and perspectives of other crew members at the base and their families,

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31 Pan Am Flight 103; the 747 that exploded over Lockerbie, Scotland on December 21, 1988.

to search out and explain the characteristic ways in which the base and Air Force operate. The explanation of this significant and tragic community event pours forth through deictic discourse and you will read some of it later on.

> There can be no general argument that establishes the force of deictic explanation[32]. What we can do in general, however, is to make room for it by recognizing that deictic explanation is not only compatible with apodeictic and paradeictic explanations but is complementary to them. The former provides the orientation that the latter normally presuppose and require. [107]

But are we not yet left with an explanatory gap for understanding phenomena in the social realm?

3. Paradeictic Explanation

In articulating the explanatory gap we are faced with, Borgmann comments that deictic explanations might seem to be the only other alternative. That is, perhaps through deictic explanation we can pursue endeavors that are designed to exhibit and clarify the phenomena of the social sphere. But the term 'deictic' has been used in a more specific sense. "A deictic explanation articulates a thing or event in its uniqueness." [108] Are there not statements of more general applicability that can be made?

There is a third possibility of explanation and insight that Borgmann describes as the appropriate mode of addressing this gap between the apodeictic explanations of the sciences and the deictic explanations of our heritage. *It is one with which we try to comprehend the character of reality by discovering its predominant pattern.*

> A pattern is more concrete and specific than a law and yet more general and abstract than a unique focal thing. To illuminate reality by disclosing its pattern is a quasi-deictic explanation. Let us call it paradeictic[33] or paradigmatic explanation. [109]

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32 You are undoubtedly yet a bit bewildered concerning what this type of explanation really is. The notion of deictic explanation is abstruse and difficult to explicitly define in a way that provokes a response in one's mind such as: "Oh, ya! I see it. Now I understand what that kind of explanation is." It is something you need to experience. The best way to think about it is to think of something of ultimate significance or concern in your own life -- a religious experience or devotion, perhaps. Then think about how you would *explain* this ultimate concern, and its personal significance to you, to a friend or some other person who doesn't yet understand. You would articulate it in your own words in a way that your friend might better understand what it is about this thing that has focusing power in your life. Your description would be a *deictic* explanation. Most of us use words which are not as eloquent as the poet's poetry or the essayist's prose in the way we might present it. Nonetheless, deictic discourse is part of our everyday life when we attempt to explain significant things, events or concerns that orient and focus our lives as individuals or communities. It may help to reread this section for a better understanding of deictic explanation and I refer you to Borgmann's work for excellent examples of its use.

33 This is the etymology of the word "paradigm" from: *para*, along side + *deiknunai*, to show.

Thus paradeictic explanation is elucidation of an underlying pattern but makes no attempt to subsume it under some law[34]. Borgmann remarks that in talking about paradigms "it is convenient to use 'paradigm' both for a more or less abstract pattern and for a more or less concrete and clear phenomenon which exhibits the pattern in question particularly well." [110] This is the primary sense in Durbin's *Dictionary of Concepts in the Philosophy of Science* [111], with his secondary sense being that of Kuhn's usage; however, Borgmann's use is also the original sense *intended* by Thomas Kuhn[35].

For example, in introducing the concept of a technological device and its relation to a paradigm, Borgmann uses the example of a stereo set.

> In the pursuit of an answer to [questions of pervasive technological patterns, such as technologically recorded and reproduced music], we will have to pay attention to the sharp division between the commodious availability of music that a stereo set procures and the forbiddingly complex and inaccessible character of the apparatus on which that procurement rests. It is the division between the commodity, e.g. music, and the machinery, e.g. the mechanical and electronic apparatus of a stereo set, that is the distinctive feature [pattern] of a technological device. An object that exhibits this central feature clearly is a paradigm of the technological device. I use "paradigm," however, not only in the sense of "clear case" but also for the pattern the clear case exhibits so well; and that pattern in turn can be drawn from various points of view and at different levels of abstraction. [112]

Thus Borgmann refers to the "device paradigm" of technology. In this work I will use the term paradigm as Borgmann has defined it and it is this connotation to which the title of this methodological chapter "paradigmatic insight" refers. In this sense, a paradigm under discussion can refer to the entire "pattern continuum," from concrete clear case through various levels of abstraction of the phenomena. This, again, is closest to the original meaning and use of the concept which attracted Kuhn to adopt the term. However, the term 'paradigm' is beset with unavoidable confusion and controversy and it deserves further clarification which I present in an appendix to this chapter for the interested reader.

But first I will close my comments on paradeictic explanation with a summary of Borgmann's discussion on what counts as a pattern and how a pattern is established. We use patterns in our everyday life to recognize things (a swan, for example) and to shape things to our purpose (a template, for example). Thus, a pattern "is an array

34 Apodeictic explanation may also ferret out patterns, of course, but its structure and the focus of the explanation is one of deductive subsumption under laws. Paradeictic explanation does not seek this type of cogency. It is a type of explanation that allows us to develop an understanding of such complex phenomena as the role of technology in our contemporary lives that apodeictic explanation cannot penetrate.

35 See the discussion later in this chapter.

of crucial features, abstract and simple enough to serve as a handy device, concrete and detailed enough to pick out a certain kind of object effectively." [113] These are unproblematic uses of paradigms.

Difficulties beset us, however, when we use paradigms in areas where common agreement cannot be taken for granted, especially when its use is intended to "settle" deeply controversial issues. Even though paradigmatic explanation can seem to be concrete with a semblence of uncontrovertable evidence in the cases used as support for described patterns, paradigm case arguments are circular. [114] Borgmann points out that this difficulty is most obvious in the metaphysical realm where the dispute concerns abstract notions or involves attempts to dislodge a skeptical objection. In this metaphysical sense paradigms seem to be primitive or undemonstratable, an "all-or-nothing" situation in which you either see them or you don't. Margaret Masterman makes a similar point in her analysis of Kuhn's multiple uses of the term. She states that it is this use of metaphysical paradigms (set of beliefs, myths, etc.) that "are the only kind of paradigm to which, to my knowledge, Kuhn's philosophical critics have referred." [115]

Borgmann acknowledges that even in social science patterns, which are more extended with a number of components and features, social paradigms still exhibit a sense of circularity and lack of demonstratability, although in a more diffuse way. They should meet the criteria of consistency, precision and applicability, but given the complexity of society, there are indefinitely many patterns that can be highlighted. This is the nature of paradeictic explanation. Paradigms are not of an apodeictic nature in which cogency is sought out in terms of antecedent conditions and laws or proof by validation, as the positivists would have it.

These skeptical considerations, however, do not contest the fact that social reality seems to be patterned. Various diverse approaches to explaining society are best understood as attempts to discover the dominant pattern. [116]

> This persistent and widespread search is reasonably understood as a response to something that in fact exists. One must rest one's case somewhere; that should cause no embarrassment as long as the final move is not made in a facile or premature manner. If there is no way of reaching forever behind the givenness of reality and *if* reality is given in a pattern, then it would likewise be impossible to get back of the paradigm in which the pattern becomes explicit. And any attempt to get beneath the paradigm by grounding it in some way would then fail and find the paradigm circular and undemonstratable. A paradigm as a theoretical entity will prevail, however, if enough people acknowledge its efficacy in clarifying their vision; and the paradigm will sharpen their perception if what it teaches people to see is admittedly what they essentially do and what essentially moves them. [117]

Competition among paradigms is forever inconclusive. A semblance of one paradigm's victory over another or attempting to show that one's own paradigm comprises all others and constitutes *their* underlying pattern results in pseudovictories which are empty or dubious. Paradigms do not invoke explanatory self-sufficiency as their development depends on value judgments about what *are* the essentials. What are the intrinsic or indispensable properties of a thing or phenomenon that give it its character and identity -- what is the essence of its dominant pattern? Borgmann exemplifies the question of paradigmatic essence with the following:

> "I can delineate precise patterns of heat exchange and show that all societies are heat exchange systems. I can argue that whatever is called bargaining, allocation of resources, or political action is at bottom nothing but a mode of exchanging heat. But is it so essentially?" [118]

Thus, the virtue of the paradeictic explanation and the paradigm is not that it "proves" something. Its virtue resides more humbly in its illuminating force and it is this property upon which I will rest my case for a paradigmatic framework for flight safety.

Summary: What It Means To Explain

In summing up, my approach to the difficult topic of the context of aviation safety boils down to the notion of explanation. Explanation is a conveyance of an understanding of a phenomenon.

The dominant model of explanation is that of scientific explanation which has its roots in the physical sciences. As a methodology it seeks to dominate its subject matter in a reductionist fashion. It seeks cogency in its logical rationalistic form by subsumption of phenomena under scientific laws and stated initial conditions. It contains cause-and-effect-chain arguments or lines of reasoning as a special case. Understandably, it is currently the dominant, if not the only way of thinking that is acceptable to the community of experts who work at explaining what is going on in the arena of aviation safety -- whether it be accident investigation, human factors research, design of aviation systems or the setting of aviation policy. We call this type of explanation *apodeictic explanation.* It may be necessary for a full understanding of a phenomenon but it is not sufficient. In particular, because of its reductionistic nature it is not well suited for an adquate explanation of the context with which the phenomenon is embedded.

Scientific explanation is lacking in scope. It cannot adequately penetrate the complexities of *human* phenomena. The complexities of sociotechnical systems and such broad-scale phenomena as the cultural and social context of technology or the context of aviation safety are left wanting for explanation and understanding.

But ambiguous phenomena represent a continuum for a spectrum of explanation. Apodeictic explanation sits at one extreme of the spectrum, its weight causing undue imbalance in the explanation continuum. There are other types of explanation that can shed ontological light on a phenomenon, that can convey even profound understanding of the nature of its reality. They can frame a phenomenon properly in its ontological context, instead of a matrix of laws. These types of explanation cannot, nor are they intended to, dominate the subject or target of explanation. They do not seek the compelling demonstration of the subsumptive apodeictic explanation that is characteristically cogent in its form. They seek enlightenment in other ways. They seek to point out, to show, to articulate features and patterns in ways that convey a deeper understanding of the phenomenon. That understanding may come merely from connections drawn among the concepts that are already present in one's mind and thus shed light on something not properly understood.

On the opposite end of the explanatory spectrum is *deictic explanation*. It is a way of pointing up, showing or acquainting one with the unique and crucial features of something -- something whose importance and significance is contained within itself. It is a way of helping one to *see* what in fact is there. It is the language that explains the unique character of something of ultimate concern -- a focal thing, event, concern, experience -- life, death, human tragedy, loss, sorrow, dedication, a spiritual experience, wilderness.

In the broad middle area is *paradeictic explanation*. It elucidates reality in its patterns through the use of paradigms. Through paradeictic or paradigmatic explanation we try to comprehend the character of reality by discovering its predominant pattern. In the process of discovering an underlying pattern, however, no attempt is made to ground that pattern by subsuming it under some law. Skepticisms regarding the paradigmatic nature of phenomena cannot be addressed in this fashion. It is descriptive. "If there is no way of reaching forever behind the givenness of reality and if reality is given in a pattern, then it would likewise be impossible to get back of the paradigm in which the pattern becomes explicit. And any attempt to get beneath the paradigm by grounding it in some way would then fail and find the paradigm circular and undemonstratable." [quoted earlier from Borgmann]

One cannot escape the experiential nature of paradeictic (and deictic) explanations. There are value judgments as to what in fact *is* the essence of a given reality's dominant pattern. And this issue must be answered by each individual in terms of whether or not their perception and understanding of a phenomenon are clarified and enhanced by the paradigm.

It is only through these forms of explanation that we can be enlightened -- can experience a depth of understanding -- about complex phenomena in a way that was not available to us before. We have an alternative to narrow positivistic criticisms such as "you can't prove that..." The intention is not to prove anything, but to enlighten with enhanced understanding. With our minds thus expanded we can be compelled to act.

The remainder of the this work will be the development and integration of four broad paradigms into a framework which characterize the contextual reality of aviation safety. Then the MAC 40641 accident and all that surrounds it, including the official accident investigation itself, will be pointed up as a paradigm of the context of aviation safety -- a specific and concrete example which illustrates the patterned nature of the context particularly well.

The objective is simple but fundamental: a better understanding of the context of aviation safety.

Addendum to Chapter 2:

The Box that Kuhn Opened

Finally, I close this chapter with an appendix that provides a summary of some of the confusion that has surrounded the term that Thomas S. Kuhn made famous. After reviewing even a small portion of the literature on paradigms, one cannot help but reflect on the mythology of Pandora. *Entrusted with a box containing all the ills that could plague mankind, she opened it!* Metaphorically speaking, Kuhn surely has felt this frustration as so many fields have picked up use of the term 'paradigm' from his 1962 book and attributed multiple meanings to it through pervasive and common misinterpretation of his original intent in using the term.

Kuhn's *Structure of Scientific Revolutions* (hereafter *Structure*), one of the most widely read (and simultaneously misunderstood, several scholars including Kuhn insist) books of philosophy of science, is cited by ardent admirers as the basis for their use of the term 'paradigm'. Much of the misunderstanding and controversy concerning the term 'paradigm' and the central concepts in Kuhn's book arises from his own ambiguous use of the term. "That the book which Kuhn *believed* he had written is virtually unknown has, interestingly, been largely responsible for both the fanatical adulation and the opprobrium accorded to *Structure*." [119] Since its publication in 1962 *Structure* "has become nothing less than a bible for countless scientists, historians, sociologists and psychologists, and has at the same time been treated as nothing less than heresy by most philosophers of science. ...The focus of the controversy over the book has been Kuhn's use of the word 'paradigm'. ...only with great difficulty could [Kuhn] have left the concept of 'paradigm' more open to misinterpretation than he did." [120]

Kuhn, himself, muses that the fundamental obstacle to a proper understanding of *Structure* results from the fact that the term 'paradigm', as employed in the book has caused a "constellation of confusion" which has handicapped him as well as his critics. "Monitoring conversations, particularly among the book's enthusiasts, I have sometimes found it hard to believe that all parties to the discussion had been engaged with the same volume. Part of the reason for its success is, I regretfully conclude, that it can be too nearly all things to all people." [121]

In 1961, one of Kuhn's colleagues who reviewed a draft of his manuscript warned, "Those who react negatively to your point of view will brush you aside, I fear, as the man who grabbed on to the word "paradigm" and used it as a magical verbal wand to explain everything!" [122] Margaret Masterman, with high respect for Kuhn [123], nonetheless finds in *Structure* that "Kuhn uses 'paradigm' in not less than twenty-one different senses." But his critics in philosophy didn't even recognize the variation in meaning and simply made a superficial assumption about what Kuhn meant by the term. Masterman writes:

> For not only is Kuhn's paradigm, in my view, a fundamental idea and a new one in the philosophy of science[36], and therefore one which deserves examination, but also, ...those who attack him have never taken the trouble to find out what it is [even though Kuhn's whole general view of the nature of scientific revolutions depends on it]. Instead, they assume without question either that a paradigm is a 'basic theory' or that it is a 'general metaphysical viewpoint'; whereas I think it is in fact quite easy to show that, in its primary sense, it cannot be either of these. [124]

But how could a book be so misunderstood and yet be so popular? Both the misconception of the nature of Kuhn's central arguments as "other than philosophical" and the book's simultaneous accessibility to the general scientific community are due to the fact that "Kuhn, having had little formal training in philosophy[37], rarely uses the technical vocabulary of that discipline and refers to only a few philosophical texts." [125] Kuhn first introduced the term 'paradigm' in a paper called "The Essential Tension" presented at a conference in 1959 and later published in its proceedings. However focused its first intention, it quickly got away from him. "That [paradigm] concept had come to me only a few months before the paper was read, and by the time I employed it again in 1961 and 1962 its content had expanded to global proportions, disguising my original intent." Kuhn reflects on the speed and extent of the expansion by comparing his original paper and a revised version he wrote not too long after to give at a later conference: "Because of that expansion the two papers seem to be making different points, something I had by no means intended." [126]

36 It was not new to the philosophy of science, but obsure and not widely used.

37 His PhD is in Physics and he then immediately turned his professional work to the history of science.

Kuhn was influenced profoundly by three philosphers, either directly or indirectly, that lead him to pick up the notion of a paradigm. Georg Lichtenber first used the term more than two centuries ago to denote a central component of the process of scientific development. Later the term figures prominently in the works of Ludwig Wittgenstein. And finally a book by Ludwik Fleck had an impact on Kuhn who, in his own words, says "in more ways than I can now reconstruct or evaluate." [127] Kuhn's adoption of the term stemmed from his realization that concepts such as "force" and "mass," or "mixture" and "compound," were not taught by definitions but through standard ways to solve problems in which terms like "force" or "compound" figured. If young scientists accepted a sufficient set of these standard examples, he reasoned, they could model their own subsequent research on them without needing to agree about which set of characteristics of these examples made them standard. Kuhn, reflecting on his thinking at the time, continues:

> That procedure seemed very close to the one by which students of language learn to conjugate verbs and to decline nouns and adjectives. They learn, for example, to recite *amo, amas, amat* ...and they then use that standard form to produce the present active tense of other first conjugation Latin verbs. The usual English word for the standard examples employed in language teaching is "paradigms," and my extension of that term to standard scientific problems like the inclined plane and conical pendulum did it no apparent violence. It is in that form that "paradigm" enters "The Essential Tension," an essay prepared within a month or so of my recognition of its utility. ...Unfortunately, in [the process of writing *Structure*] paradigms took on a life of their own. ...Having begun simply as exemplary problem solutions, they expanded their empire to include, first, the classic books in which these accepted examples initially appeared and, finally, the entire global set of commitments shared by the members of a particular scientific community. That more global use of the term is the only one most readers of the book have recognized, and the inevitable result has been confusion: many of the things there said about paradigms apply only to the original sense of the term. Though both senses seem to me important, they do need to be distinguished, and the word "paradigm" is appropriate only to the first. Clearly, I have made unnecessary difficulties for many readers. [128]

Thus, Kuhn accepts partial responsibility for some of the problems and he even abandons the term in other writings as he sees the lucidity of his central points obscured by misconceptions of the term. For example: "...the revolutionary process by which an older *theory* is rejected and replaced by an incompatible new one;" (emphasis added) and in his footnote to this phrase he says: "Elsewhere I use the term 'paradigm' rather than 'theory' to denote what is rejected and replaced during scientific revolutions." [129] And in refering to Masterman's compilation of its usage, he says: "Whatever their number, the usages of 'paradigm' in the book divide into two sets which require both different names and separate discussions." [130] And elsewhere, with reference to these two sets he states, upon reflection of the clarification needed:

> A new version of my *Scientific Revolutions* would open with a discussion of community structure. Having isolated an individual specialists' group, I would next ask what its members shared that enabled them to solve puzzles and that accounted for their relative unanimity in problem-choice and in the evaluation of problem-solutions. One answer which my book licences to that question is 'a paradigm' or 'a set of paradigms'. (This is Miss Masterman's sociological sense of the term.) For it I should now like some other phrase, perhaps 'disciplinary matrix': 'disciplinary', because it is common to the practitioners of a specified discipline; 'matrix', because it consists of ordered elements which require individual specification. All of the objects of commitment described in my book as paradigms, parts of paradigms, or paradigmatic would find a place in the disciplinary matrix, but they would not be lumped together as paradigms, individually or collectively. Among them would be: shared symbolic generalizations, like '*f=ma*', or 'elements combine in constant proportion by weight'; shared models, whether metaphysical, like atomism, or heuristic, like the hydrodynamic model of the electric circuit; shared values, like the emphasis on accuracy of prediction, discussed above; and other elements of the sort. Among the latter I would particularly emphasize concrete problem solutions, the sorts of standard examples of solved problems which scientists encounter first in student laboratories, in the problems at the ends of chapters in science texts, and on examinations. If I could, I would call these problem-solutions paradigms, for they are what led me to the choice of the term in the first place. Having lost control of the word, however, I shall henceforth describe them as exemplars. [131]

In his postscript to the 1970 edition of his book, he attempts another recovery, the significance of which still seems to be lost to most readers: "I suggest the desirability of disentangling that [paradigm] concept from the notion of a scientific community." This is the sociological context of the term so ubiquitous in the literature of the applied fields as it has come, in peoples minds, only to stand for "bodies of knowledge" or "the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community." The philosophically deeper notion of paradigm, Kuhn states, is the second, more concrete sense that he there refers to as exemplary past achievements. "It denotes one sort of element in that constellation, the concrete puzzle-solutions which, employed as models or examples, can replace explicit rules as a basis for the solution of the remaining puzzles of normal science." [132] In this latter sense Kuhn is drawing on the illuminating force of paradeictic explanation as opposed to just providing a label for "a constellation of elements" shared by a scientific community.

Kuhn has made these three concerted and related attempts to clarify his notion of paradigms and recapture the originally appropriate meaning as we have seen Borgmann use the term: as a pattern and a concrete example of that pattern. Borgmann acknowledges his debt to Kuhn [133] as well as the difficulties and ambiguities that have beset Kuhn's use of the term.

> Thomas Kuhn has ...called attention to the paradigm as an instrument of elucidation and explanation. His turn to the paradigm and the attention which his endeavors have received reflect an explanatory need which art and science have not met and which the paradigm seems to fulfill. [134] ...[However,] the difficulties and ambiguities in Kuhn's use of the term are legendary. They make it advisable to be as clear and modest as possible in one's claims for paradigms. [135]

When discussing Kuhn's work, the recent philosophical literature has recognized and accepted the original misuse of the term and has, in large part, dropped the excess baggage[38] to get at the more profound issues of "communities" and "change" in science that were initially raised by Kuhn. When the term is used now in the scholarly literature, it seems to be used in a more articulate sense and/or is clarified at the point of use as to which sense the author intends the term to denote [136].

Borgmann is critical of Kuhn, however, for missing the essential power of the paradigm in illuminating broader phenomena of the everyday world. In particular, in his attempts to recover his original use of the term, Kuhn seems to miss the broader context by not taking the paradigm as the pivot of an explanation *sui generis*. Borgmann writes:

> Kuhn's employment of "paradigm" is beset by ambiguities which often border on misunderstanding of the distinctive force of this notion. Especially in his later elaborations, Kuhn seems inclined to subsume the stronger under the weaker, i.e., to reduce the paradigm to a matter of psychology, sociology, evolutionary theory, or value theory. These are the disciplines ...whos promise of guiding power[39] must remain empty. Another limitation of Kuhn's investigation is the straightforward one of explicitly excluding the everyday world from the influence of paradigms and their changes. Hence one must go beyond Kuhn in pointing up the paradigm as an explanatory device in its own right and in extending its application to the changes in the everyday world. [137]

In his attempts at recovery, Kuhn wants to refocus his full notion of the paradigm concept on the "exemplar," or exemplary past achievements in standard problem-solutions which provide the "pattern" for newcomers to the field to follow, thus providing the continuity of the "normal" puzzle-solving phase of science. Kuhn's "paradigm shift" is the dropping of this body of exemplary past achievements and much, if not all, of the background assumptions, theory and practices they entail, in favor of a new body of exemplary achievements which have solved (or more effectively address) the growing set of anomolies under the old paradigm. But he fails to connect the term to this profound *pattern* of the history of scientific development (a nonincremental accumulation of knowledge through periods of "normal science" separated

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38 The controversy is no longer over the term "paradigm," although it does seem to be fair fodder, still, for sarcastic digs from some of his critics.

39 Recall our previous discussion on the loss of world articulating power of the apodeictic nature of the sciences.

by revolutionary change, according to Kuhn) which is a *paradigm* of science itself; and the physical sciences, from Copernicus to Newton to Einstein, represent a more or less concrete example which illustrates the pattern particularly well! It is clearly a *paradeictic explanation* of scientific progress, as Kuhn has seen it. Thus, Kuhn's attempted recovery of "paradigm" through the concept of "exemplars of past achievements," while it certainly is an application of the notion "paradigm," is narrowly focused and still is not *the* essence of the concept itself.

The popularity of Kuhn's book has positioned him, in most peoples' mind, as the "father" of the paradigm and the ultimate authority on the meaning of the term; obviously he is not. But, if we take a quantitative look at citations, one cannot deny that the literature of the scientific disciplines and applied fields is replete with instances of its use that cite him as the authoritative source of the concept, as these writers have interpreted it; yet, overall its use demonstrates a lack of understanding and full appreciation of the essence of this term. With respect to the applied field literature, where the common use of the term seems to have settled into a label for the "fuzzy set" notion of shared commitments, background assumptions, theories, symbolic generalizations, models and values, etc. of a disciplinary community, the question of recapture remains dubious. Its ubiquity and multivalent use is evident to one as he or she reads the literature of their own field, as it is as well in such comments from detailed studies of paradigms like those of Kisiel: "The pivotal term of [Kuhn's *Structure*], 'paradigm,' has become a staple in academic parlance, and beyond" ...[and with respect to all the misunderstandings and confusion] "the essential message of the man's work is too easily drowned out in the cacophony of controversy." [138] And in Eckberg and Hill:

> The impact of [Kuhn's] work has been felt in such diverse fields as history, philosophy, political science, anthropology, sociology, theology, and even art. Students of each of these disciplines, in assessing the relevance of the paradigm concept for their own concerns, have begun arguments which continue to this time. ...The results of these attempts [refering now specifically to their detailed study of sociology] have been far from satisfactory. In fact, there are almost as many views of the paradigmatic status of sociology as there are sociologists attempting such analyses. ...One explanation of this phenomenon is that a number of sociological theorists have misused the paradigm concept. ...Multiple interpretations of the term have had the effect of allowing sociologists to cite Kuhn as a source which at the same time, they are not taking seriously the implications of his position, ...moreover, the writers discussed here were largely aware of Kuhn's (1970) later explication of the concept. ...the paradigms spoken of by sociologists are nebulous, shifting entities, indicating whatever one wishes them to indicate, and are limited only by the theorists' imagination. [139]

De Mey calls these type *paradigm hunters* who, while promoting the search for a paradigm to explain the troubles in their field, lack a precise model of what a paradigm is so the application of the remedy is anything but clear. [140]

Before we explore the use of the term in this manner a bit further, let me provide a socio-biological metaphor that I believe will serve as a sort of *paradigmatic explanation* of the introduction and explosive spread and unwitting adoption of this term of obscure European origin, "paradigm," and the proliferation of its inappropriate connotations. The metaphor concerns the invasion of plant communities all across North America (but especially the west) by a weedy species of annual grass called "cheatgrass" (*Bromus tectorum* L.).[40] [141]

> This weed [think 'paradigm misuse'] was introduced from Europe to North America in the late 19th century (circa 1889) most likely as a contaminant of good grain stock [think, perhaps 'Kuhn's original intent' as in his 1959 "The Essential Tension"], possibly in a single event [his 1962 book]. Its wide ecological amplitude [think 'ability to flourish in all kinds of environments'] allowed it to spread naturally by invading disturbed [no pun intended] plant communities. In addition, before its weedy nature and questionable value were fully understood it was also deliberately re-introduced by both scientist and peddler, extolling the virtues of a new "100-day" miracle grass. For about the first ten years it slowly increased its range, which was still quite small and confined to local populations. Mack writes, "there is little indication in the reports of the time that the observers recognized the plant's potential for spread." Over the next 15 years, however, the weed became both widespread and locally abundant. It's persistence in the seed bank of grain fields [applied literature] "led unknowing farmers to think their wheat seed had degenerated into a weed, and in the parlance of the day, the wheat had "cheated" the farmer [reader of various articles?]."
>
> By this time it was becoming both a widespread and dominant weed, spreading to various types of agro-ecosystems and replacing indigenous species in their original range. The spread was further accelerated "unwittingly by the unregulated exchange locally [think 'within a disciplinary community'] of contaminated alfalfa seed." By 1916 it hit the "10 worst weeds" list. By 1930, "*B. tectorum* seems to have occupied its current range, like a group of coalescing "leopard spots" which rapidly covered the [entire intermountain plant] province [think 'scientific literature']." There was a definite acceleration of range expansion between 1915-1930 which Mack likened to a "compound interest disease;" an epidemic,

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40 I would like to thank my good friend Tom Vernon, cattleman and range manager, for discussions which helped me better understand the ramifications of this noxious weed.

> ...limited in its initial expansion by lack of inoculum (only small populations) and number of foci (points of entry), [but later] limited by neither inoculum nor tissue to be infected (available territory). Finally, by 1930 the lack of suitable unoccupied territory restricted further range expansion. ...one simply woke up one fine Spring to find the range dominated by a new weed. ...[With ideal weed characteristics,] its success as a colonizing species in western North America has been so phenomenal as to almost exterminate the evidence. [It is now] the most ubiquitous alien in steppe vegetation in the intermountain west of North America, ...demonstrating the degree of success an alien may achieve when preadaptation, habitat alteration, simultaneous with entry, unwitting conformation of agricultural practices to the plant's ecology and apparent susceptibility of the native flora to invasion, are all in phase. ...Seldom in the recent transformation of the Earth's vegetation by mobile Occidental man and his plants has the vegetation of such a large area been transformed so swiftly and (apparently) permanently.

The cheatgrass metaphor may represent the permanent ambiguity and indeed the dominance of the common connotation of the term 'paradigm' that we must now learn to live with; it is literally impossible to eradicate the cheatgrass. However, if we are not to fall into the confusion which obscured Kuhn's central theses and his own use of the term in the early debates on his ideas, we should heed the ecological lesson. Awareness of the occurrence of more than one usage of the term 'paradigm' should reflect prudence in its identification and use whenever one intends to "replant" it.

Sardonic humor aside, what the cheatgrass metaphor misses entirely, however, is the *need* for a term that characterizes the shared practices, beliefs, fundamental social expectations and values of a disciplinary community. In this sense, *paradigm* has been a "breakthrough" word for coalescing in our minds those fuzzy things disciplinary communities share.[41] This context is undoubtedly the attraction that led to the rapid adoption of the term for that connotation. The term in this "fuzzy" sense has high utility (and is less clumsy, perhaps, than Kuhn's "disciplinary matrix" which never replaced it anyway), allowing us to speak of the differences among the social disciplinary communities and their respective perceptions of reality. In interdisciplinary research, for example, it can help us get past differences by having a label which we can use to refer to all those fuzzy notions that tie a community together and allow easy and free exchange of ideas through shared meanings, expectations and perceptions. [142] It is these same shared "paradigms," however, which seem to hinder cross-discipline exchanges. [143] But the term can used to help facilitate communication across disciplines by providing a way to say such things as: "Both of you [participants from different disciplines in an interdisciplinary arguement, for

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41 I am indebted to David Bella for pointing out this perspective to me, as well as the observation that the soil I planted my cheatgrass metaphor in might be a bit acidic.

example] are viewing the problem from different *backgrounds* which reflect the "paradigm" or "paradigms" of your respective communities. In other words, you are not communicating your ideas to each other. We need to expand our "paradigms" or generalize them in this discussion so we can share the same meaning of the terms and concepts we are using." Bella has made good and effective use of the term in this sociological sense for understanding the sociological character of knowledge -- a key concept that Kuhn put forth and initially let the term expand to cover these things.

Marc De Mey would agree with Bella that this sense of this term should not be lost but clarified. He writes that, although

> ...Kuhn has deplored the fact that his 1962 monograph has induced an inflation of the term paradigm so that it has become a label for the entire set of beliefs governing the behavior of a scientific community ...the composite nature of a paradigm in the broader sense is not necessarily in contradiction with the unifying function attributed to it. ...The fascinating aspect of paradigms is that such amalgamations seem able to develop into stable cognitive structures that bring coherence and directionality in the work of scientists. ...A rejection of the broader notion of paradigm at this stage could be like rejecting the notion of face after discovering that what we had first tentatively recognized as a face now turns out to consist of a nose, two eyes and lips in an asymmetric smile. [144]

And with respect to the social nature of paradigms he states:

> Each scientist does not develop his paradigm as a solitary enterprise. Paradigms result from interactions with others and attempts to understand them. Understanding comes down to perceiving the world in terms of the world model of the other. The locus of a paradigm is not the brain of the individual scientist but the community of those scientists who can understand each other because they see their world in a highly similar way and who see their world similarly because they have evolved as one group through intensive interaction. The *paradigm* is *both cognitive* and *social* in nature and as an explanatory unit entirely in line with [the] position that "perception and communication are one *whole*." [145]

Another biological metaphor is appropriate for this perspective. It is that of the cell structure. De Mey summarizes the broader perspective of paradigm in terms of an anatomical dissection yielding four different components: symbolic generalizations (f=ma, for example); metaphysical beliefs or models which provide preferred analogies combined with a reality; values such as simplicity, consistency and accuracy; and exemplars as a paradigm in the strict etymological sense of the term (i.e. a pattern of interest and prototypical example which exhibits the underlying pattern). He then views the broader sense of a paradigm as having resemblance to a cell structure:

> ...the exemplar in the position of the vital nucleus with floating around in the cytoplasm other components such as symbolic generalizations and metaphysical models. Notice the heterogeneity of this conglomerate. A paradigm cannot be reduced to one or more general ideas (symbolic generalizations), neither can it be reduced to one or more inspiring metaphors (metaphysical beliefs) nor to a set of specific skills for handling particular problems (exemplars). To arrive at a paradigm, one needs all these various components together and in a successful combination. [146]

But De Mey himself, while putting forth an explicit justification for a clarified broader meaning of the term, like Kuhn still misses the *essence* of the concept. This characterizes well what the common and dominant connotation of the term has become; it is merely a label for those things noted above. One might be able to make a reasonable argument, perhaps, that this use of the term is consistent with its etymological base in that, what has been described about disciplinary communities is in fact a "pattern" we see that characterizes what the communities have in common and an individual disciplinary community, Newtonian physics, for example represents a more or less concrete example of that pattern. However, unless one clarifies the word's meaning when first introduced, as Bella, Borgmann and De Mey do, the risk of ambiguity is high as has been noted in some of the literature I cited earlier.

The unfortunate result of the dominance of this more common use of "paradigm" is, however, that it has obscured, if not buried, its illuminating force as *paradeictic explanation*. The utility of the term in its original sense to mean a pattern that characterizes some fuzzy phenomenon (flight safety, for example) and more or less concrete examples or specific exemplary instances which explicate that pattern (the flight 40641 tragedy, for example) never comes to light. If we grant the argument in the paragraph above, the essence of its meaning becomes hidden by its use as a label for those things disciplinary communities share. Albert Borgmann has done us a great service through his eloquent resurrection of the deeper and more powerful notion of the **paradigm as paradeictic explanation** (of technology, in his work) which provides a phenomenological tool for the examination of the reality of everyday life. I highly recommend reading his works to appreciate the full impact of his message.

Chapter 3

Overview of the Framework

Before we begin a development of the contextual paradigms in some depth we will preview here the essence of my thesis. It should give you a good conceptual framework, albeit of a skeletal nature as yet, upon which we will fill out the meat through the next four chapters.

As this whole conceptual development will be new to most readers it would be helpful, I believe, to begin this overview by pulling together what we have developed thus far into a sort of "metapattern" or "metaparadigm," if you will.

A Metaparadigm for the Explanation of Aviation Safety

These concepts are complex and difficult to "boil down" into a simple presentation without loss of richness. Figure 3.1 is an attempt to do just that with the hope that richness is not lost but jelled.

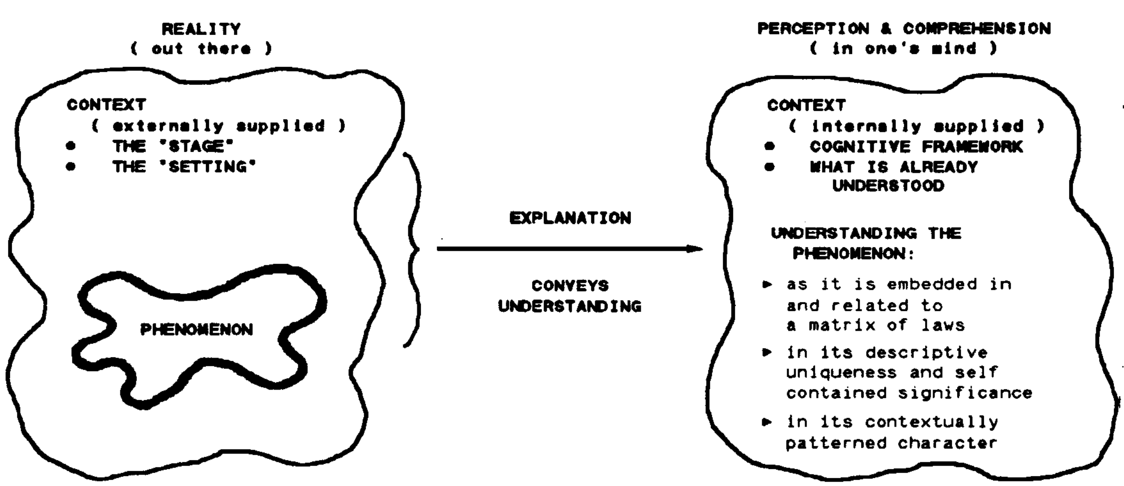

Figure 3.1 A metaparadigm of explanation.

Figure 3.1 is an abstract illustration of the abstract concepts we have developed thus far. Its primary value is to serve as a mental construct that illustrates the relations among some of the concepts we have discussed with their associated labels (terms) or "tags." Through this mechanism I will also be able to preview briefly some of the key concepts that will be developed more fully later on.

To overview, review and preview some of the terms which are nothing more than labels "tagged" to the richer concepts I will begin with the label 'phenomenon.' A *phenomenon* is any occurrence or fact that is directly perceptible by the senses. It is that which appears real to the senses, regardless of whether its underlying existence is proved or its nature understood. It can be a thing or device such as an airplane, an event such as an accident, a communication process such as that between pilot and controller, or even something more abstractly complex such as flight/aviation safety which can be characterized by many things including, for example, the absence of any tangible accidents for some period of time. A phenomenon exists within a *context* that is external to the perceiver. I have illustrated the puzzling phenomenon with its amorphous connections into its context as an odd shaped figure with fingers of various forms and sizes meshing into the contextual field, if you will. The line circumscribing the phenomenon should not be construed as the abrupt edge it looks like on paper, for we are talking about one fuzzy notion (phenomenon) meshing with another fuzzy notion (context).

Explanation is the conveyance of understanding. And *understanding* is the process of locating a puzzling phenomenon in a broader framework of concepts and relations in one's mind. Through understanding one perceives and comprehends the nature and significance of the phenomenon. Something becomes clear that was not previously clear by virtue of the fact that it gets positioned in a framework of things we already understand. We then *understand* the phenomenon because we "see" how it relates to other things we already understand.

That is, when we perceive and comprehend something we are doing so from an *internally supplied context.* This is our *cognitive framework* which represents our working model of the world.

Now, the broader framework of concepts and relations within which the puzzling phenomenon gets located can be a "matrix" of scientific laws and relations. As I have emphasized earlier, this is the predominant mode of understanding phenomena. If you are an engineer, scientist or systems analyst, you undoubtedly view, understand and explain the world predominantly from this *apodeictic* framework. You are trained to view it that way and it is likely difficult for you to believe that you can really understand it any other way. Thus you would attempt to force all of your explanations into this mode because you feel comfortable with it. You want things boiled down or laid out in nice ordered lists and precise definitions, maybe even explicit models of some sort, so that you can "deduce" an understanding of the world from them. You are perhaps uncomfortable with experiential understanding. It's too vague or fuzzy, maybe, and when you try to grab onto it with an apodeictic frame of mind it just dissipates through your mind's fingers. The problem is that such experiential understanding does not come from hard deductive logic.

There are indeed many other ways that a framework of concepts and relations can be built and a phenomenon positioned within them. Suppose a person relates an experience to you by telling you a story and describes how they reacted to the experience. And then you said, "I can understand where you're coming from," or "I can understand how you felt." You wouldn't say that because you placed the phenomenon that the person described in a matrix of scientific laws and *deduced* her reaction to it. You would say that only if what she had related to you fit into a framework of relations that was built up from similar situations that you had experienced. So an explanation of a phenomenon (the person's experience) had conveyed understanding and it had nothing to do with subsumption under scientific laws. It had everything to do with placing it in your own framework of concepts and relations.

Now suppose that you had never experienced a similar situation. Suppose, for example, the experience that she was relating to you was a recent backpacking trip into the wilderness. Suppose you have always lived in the city and had never had such an experience. It would be hard for her to *explain* what it was like because there is no familiar place to stick it in your mind. Or maybe you had had one experience and it was an awful experience. You got blisters on your feet, you were cold and wet the whole time and could not get a fire started because it poured rain continually. It is still unlikely that she would be able to explain to you the way in which her wilderness experience helps her to focus her life and keep the world in proper perspective. But she may try by attempting to tap into analogous experiences you may have had such as a quiet early morning walk in the city arboretum. It's not the same, of course; you'll never really understand her experience without having had a similar experience. But through her words and her testimony of the kinds of things the experience does for her, why she is motivated to make it a part of her life, and through some analogous experience you may have had upon which you might be able to "tag" some of the same labels, you might just be able to understand a bit of what she means.

What I have been describing is *deictic* explanation. It is a type of explanation that does not try to "prove" to you in a compelling way that backpacking in the wilderness is what everyone needs to do in their lives. It hopes, more humbly, to enlighten you by conveying an understanding of the unique characteristics of this focal activity that helps her engage the contextual realities of the world more fully and completely. It is sympathetic to your lack of such an experience and it invites you to see for yourself. The significance of the experience is not contained in a compelling argument about it, but in the experience and the wilderness itself.

You are reading these pages, presumably, because you have some interest in flight safety. My objective is to expand your thinking about flight safety. The first hurdle I have attempted to overcome along this path is to expand your cognitive framework to include an enhanced understanding of what it means to explain something -- explain anything, for example flight safety. You need to hold new concepts of "explanation" in order to "understand" how I am approaching the subject matter of "the context of aviation safety."

I have argued in the previous chapter that contextual complexity does not lend itself readily to apodeictic explanation, especially since humans are part of the contextual matrix. Now, I might be able to relate to you some of the unique focusing significance of an aviation disaster, say, through deictic explanation but it alone would not take us far along the path of understanding the overall context of aviation safety. This context is ontologically patterned. Thus it is by ferreting out and describing the essence of the patterned character of the contextual reality of aviation safety that I hope to further expand and restructure your cognitive frame -- in short, the way you think about and understand aviation safety. The path to this end is through *paradeictic* explanation.

Again, I will try to illustrate these abstract notions further by expanding on the abstract figure above.

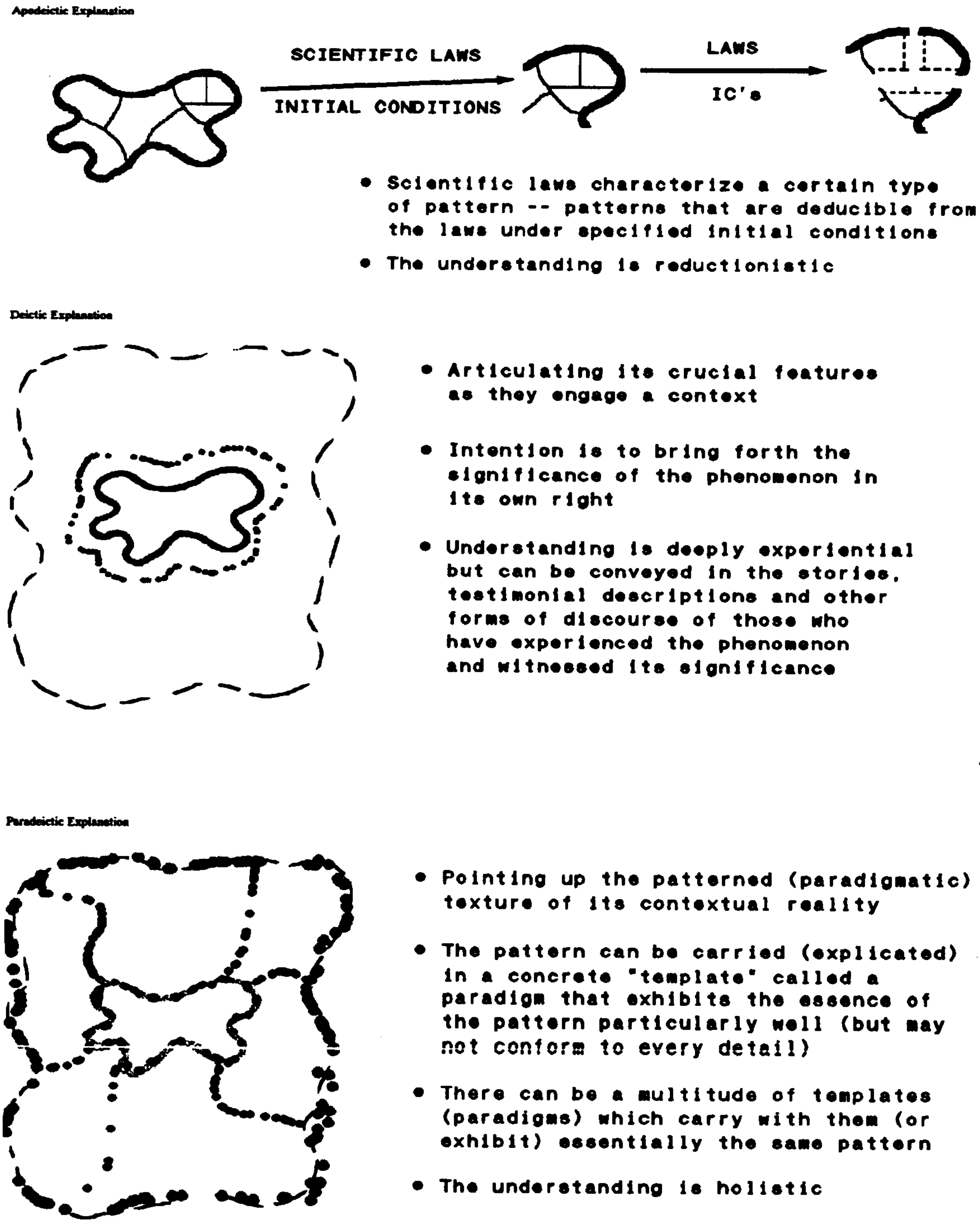

Figure 3.2 Explanation of a phenomenon and its context.

Finally, we must keep in mind that if we characterize contextual reality by patterns (paradigms) and we characterize the patterns by concrete examples which carry the patterns (also paradigms) we can see the difficulty in grounding the pattern apodeictically.[42] Such efforts lead to circularity and are fruitless. But if we reject the paradeictic approach to explanation because it does not have an apodeictic "deductive" structure we forgo the insight and understanding we gain by "seeing" the patterns and relations that in fact characterize the contextual reality.[43] Paradeictic explanation does not seek cogency through deductive logical form. It does seek to convey understanding by tieing together contextual relations and forming new relations and linkages in one's cognitive framework. Understanding comes from seeing the phenomenon for what it is in relation to its context. Then other inferences can be made from this realization.

A Preview of the Paradigmatic Context of Aviation Safety

In the development that follows in subsequent chapters I will show that the context of aviation safety if patterned. Accidents are patterned in a certain sense that makes certain types "normal" or expected. The context of aviation safety is patterned in a cognitive sense, some of which I have hinted at already. And aviation safety is patterned as a phenomenon embedded within technological and organizational patterns that characterize our modern technological world.

What are these patterns? These patterns cannot be properly understood without reading the development for each of the four paradigms in the following four chapters. However, without some overview of where we are going, I fear that you will be impatiently asking exactly that question and I may lose you as you attempt to wade through the details of the development.

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42 In fact I resist the temptation to provide generic characteristics of "patterns" in a list form or some other uniform format from which one could supposedly take and apply along with some "rules" to discover "paradigms." The essence of patterns themselves is context dependent and experiential. Surely they contain concepts and relations but beyond that any attempt to procedurally "linearize" the approach would automatically constrain and limit it. One would be following an apodeictic approach to a paradigmatic investigation: Here's the general criteria and format, these things fit the general criteria and format, therefore we can deduce that this is a "paradigm." One must endeavor to break out of that kind of thinking for this kind of understanding. In the concluding chapter, however, after you have gone through the entire development and have seen its explication in the examination of the MAC 40641 accident, I will summarize some guidelines to help point out paradigmatic contextual elements that should be looked for and considered for a full understanding of the accident.

43 This certainly does not imply that nothing in the context can be explained apodeictically. In fact some things that may be currently only explainable paradeictically might have aspects that later on are found subsumable under some laws yet undiscovered. But it is a fallacy to say that all things are explainable apodeictically, even though we just haven't yet found the right laws that pertain. The reductionistic deductive structure of subsumption under laws just doesn't lend itself to all phenomenon to be examined.

Figure 3.3 again shows in an abstract sense the problem at hand, but specifically annotated for aviation safety. The context is shown to contain four conceptual elements: a cognitive element; an element that is characterized by accident patterns; a technological element; and an organizational element. One might conceive of a cultural element as well, but in the world related to aviation safety the culture is essentially technological and organizational and it will be contained within those developments.

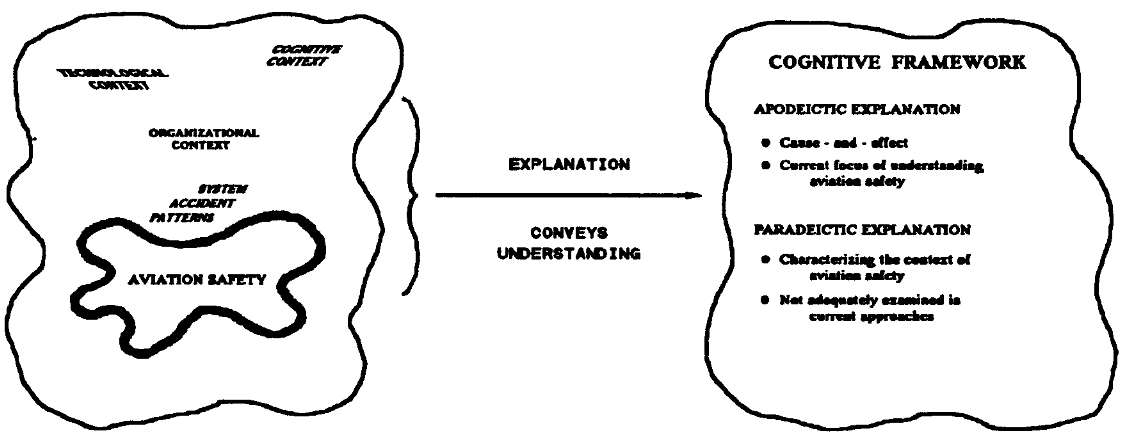

Figure 3.3 Explanation of Aviation Safety

These four elements do not represent a partition of some abstract contextual space. They are a convenient way of organizing the examination of the paradigmatic nature of the context of aviation safety. There is much overlap among them. Briefly I will describe them as follows.[44]

The Cognitive Paradigm

In the cognitive paradigm the broad concept of *context* is identified as really two things: an externally supplied setting or "stage" with which phenomena are engaged and an internally supplied framework which patterns the perceiver's thinking and understanding about the phenomenon and its context. We might visualize this *framework* as a network of concepts and their relations. Each concept itself may

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44 These developments are well cited and acknowledged in their respective chapters. Thus no attempt will be made in this overview/preview to cite appropriate literature here.

invoke its own cluster of concepts. There is not just one overall framework. The cognitive framework is something that is triggered by some stimulus (in the mind or in the environment) that brings up concepts and relations as they are needed.

Such frameworks are built up over time as we go through life learning and experiencing the world. Thus they represent our "world view" or "expectancy set" for future encounters with reality. These later encounters are characterized by two patterns. One is that with this expectancy set we are able to quickly and effortlessly perceive and understand the world without processing all the details of information in the environment. We fill in the details from our framework once it is recognized that what we are perceiving fits certain patterns of concepts and relations in our mind. The more experience we have with certain types of phenomena the more we are able to quickly conjure up the familiar situation in our mind and understand it and/or react to it.

The pattern which is corollary to this is that we tend not to perceive and understand incongruities. That is, if something we are trying to perceive or understand has elements itself or in its context that do not fit our expectancy set we tend not the recognize them or even know that they exist. We tend to see and understand what we expect to see. Further, once we believe that we understand something to be a certain way we tend to lock onto it and resist information to the contrary.

This has implications at both extremes. On a vary narrow scale the controller, for example, may have perceived that he was called by the Navy plane and understood the situation as that he gave him a clearance to descend to five thousand -- even though there are indications that it was the MAC plane who called and got the clearance. At the other end of the spectrum, for broad scale frameworks it may be difficult for someone to let go of the notion that everything can be explained apodeictically because that is how they have always (they believe) understood the world. The same point can be made with thinking about flight safety in an apodeictic cause-and-effect mode. One believes they are getting the whole picture with this approach -- in fact, perhaps they cannot imagine how you couldn't be getting the whole picture. This is a type of "mind lock" and it is important to address in our understanding of the context of aviation safety.

The Paradigm of Normal Accidents

Normal accidents are characterized by unforeseen and/or temporarily incomprehensible interactions of multiple failures. They are "normal" in the sense that such interactions are to be expected. Two system characteristics exacerbate the propensity for these normal, or more formally system, accidents: interactive complexity and tight coupling. The patterned effect is illustrated in Figure 3.4.

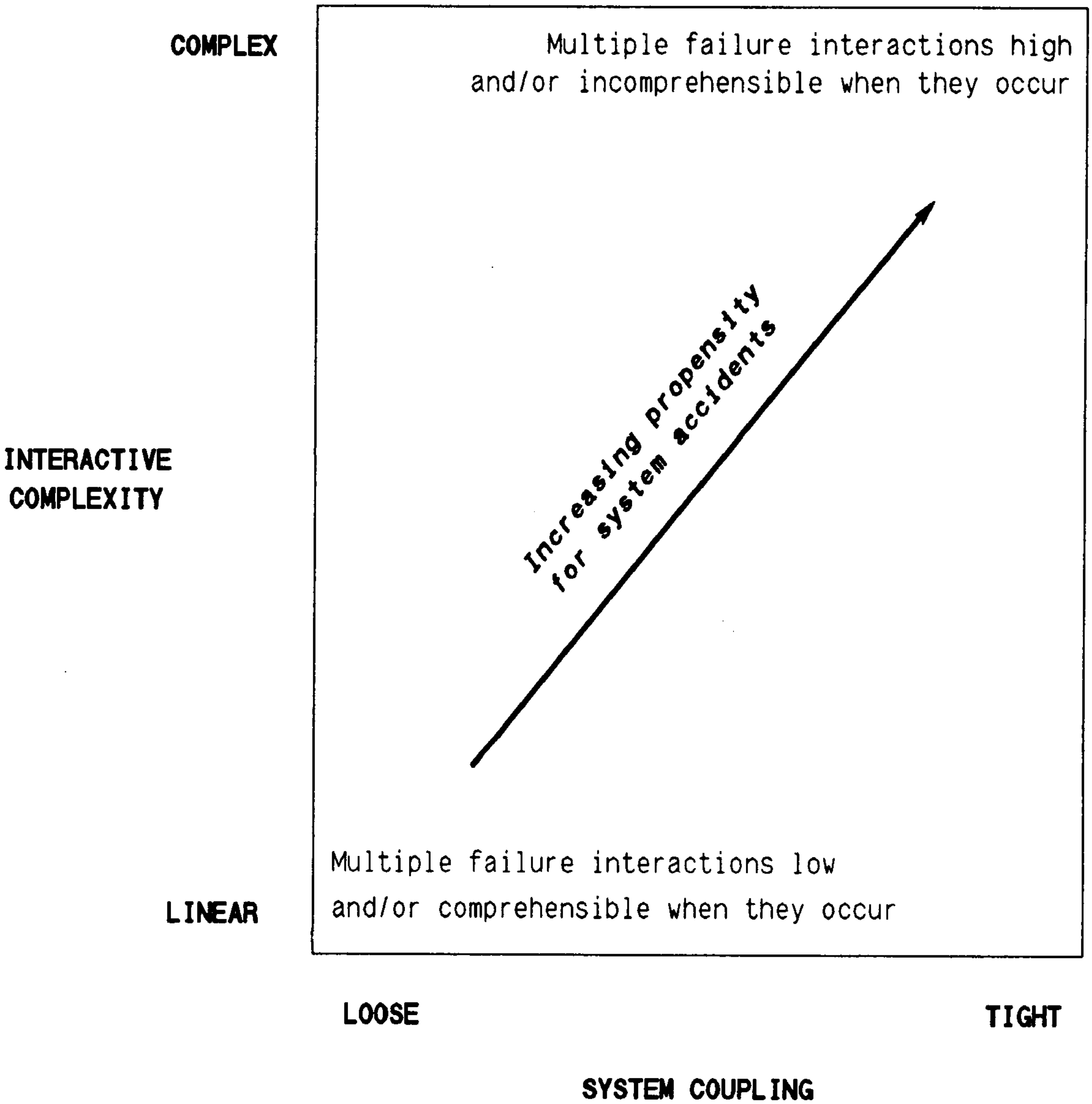

Figure 3.4 System Accident Characterization Matrix

The Paradigm of Technology

The paradigm of technology is carried in the pattern of the device. There is a sharp division between the machinery of the device and the function of the device. The machinery becomes ever more complex and receding while the function becomes ever more manifest, stable and emancipated from the particular machinery itself. The purity of function leads to ever more refined needs which proliferate in an unbounded fashion. The function procures the commodity[45] which serves the need. Technological progress is measured by "availability." A commodity is available if it is ubiquitous, instantaneous, easy, and safe.

Ubiquity and instantaneity are directly experienced in the consumption of the commodity. Ease of use is also directly experienced but less so for much of the direct use is experienced by operators. Safety is experienced indirectly in the absense of safety failures (accidents). Thus there is paradigmatic pressure to serve the primary (first two or three) aspects of availability at the expense of the fourth (safety). The background machinery of technology operates and sustains itself through a set of expectations which influence the behavior of those who participate in the labor side of technology (virtually all of us). These functionary expectations support the paradigmatic pressure for ever increasing availability in its primary elements. Safety, because it is only experienced in the absense of accident phenomena, is obsequious to the primary aspects of availability and thus, as an ambiguous margin, it represents a well in an environment of limited resources which can be technologically mined to advance the primary aspects of availability.

Anything that tends to enhance availability of a commodity can be viewed as a technological device. For example, a government agency, the insurance industry, the commercial aviation industry, and the Military Airlift Command are all devices in the paradigmatic sense. These broad scale devices procure commodities such as food for the poor, security, and rapid transportation. They are recursive in nature as their background machinery is also composed of devices such as Air Traffic Control and airplanes, which are in turn composed of devices, and so forth. The pattern of technology, however, is pervasive throughout.

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45 The term is meant to be inclusive of both material goods and services.

The Paradigm of Organizational Complexes

Traditional thinking sees organizational complexes as goal seeking institutions. This thinking is flawed and does not describe the reality of organizational complexes. Organizations are adaptive systems which tend to avoid disorder through networks of mutual dependency or coupling of local environments. The primacy of order is manifest in expectations and responsibilities of individuals working in their respective local environments. These local environments shape behaviors, actions and decisions which sustain practices, perceptions and expectations. Organizational arrangements adjust to both externally and internally induced disorders by adapting toward compatible system states. This makes the growth and spread of disorders less likely.

This pattern of disorder avoidance leads to the systemic distortion of information without the intention of organizational participants to deceive. That is distortion does not have to come from deliberate efforts to deceive, it is a normal pattern of organizational complexes as their participants carry out their functionary responsibilities.

With respect to safety, disorders (such as accidents, which constitute a physical disorder) are experienced rarely compared to the other paradigmatic aspects of availability. Thus the perception of safety changes over time in a positive direction while, in fact, it is likely deteriorating because with out some constant source of disorder resources tend to be directed away from it to more immediately experienced disorders.

Summary

With this overview in mind, we can now proceed to justify these claims in the developments that follow. These four broad paradigms which characterize the pattern of reality from a very broad perspective provide a relatively comprehensive set for a framework that can be used to guide us and help elicit the contextual information from the MAC 40641 accident. Once the development of the framework has been accomplished in the next four chapters, we will examine the MAC 40641 accident both apodeictically and paradeictically, along with an airing of appropriate deictic comment from, among others, testimony of witnesses presented before the accident board. The framework I have developed will be explicated with this accident and the accident itself will be pointed up as a paradigm that carries with it much of the contextual pattern of aviation safety.

The intent of examining the MAC accident in depth is to point up both the inadequacy of apodeictic explanation alone and the need to integrate more than one of the paradigms I have described into a framework for the context of aviation safety. By itself, apodeictic explanation misses the point and often leads to both a fundamental attribution error and a fundamental surprise error. The fundamental attribution error is the tendency to blame bad outcomes on an operator's personal inadequacies rather than attribute them to situational factors beyond his or her control. The fundamental surprise error is to avoid any fundamental meaning and to learn only the situational lessons from the localized events requiring solutions to specific problems. Fundamental surprizes are what we hope to uncover with a new framework. They refer to a profound discrepancy between one's perception of the world and the actual reality and demand a major reappraisal of the phenomenon and its context.

Finally, some brief -- even tentative -- conclusions and recommendations will be made both for the Military Airlift Command and for accident investigation and aviation safety in general. Some "metaguidelines"[46] to help those involved in this field, from policy makers to accident investigators, will be suggested. I indicated that these thoughts are tentative and modest because the whole area of research into the context of accidents and safety is like a seed just germinating.

46 I use the prefix "meta-" in several places to refer to a sort of transcending character that goes beyond the notion identified by the root term. "Metaguidelines," for example, broadly refers to more general contextual guidelines that might be used to orient our thinking about more context specific guidelines. "Metacommunication," as another example, refers to communication about the context of our communication, itself, wherein a "metamessage" accompanies the root message which provides for a contextual interpretation of the message itself. Specific meanings of such terms will be clarified, if necessary, at the appropriate point of initial usage.

Chapter 4

A Cognitive Paradigm: Implications of Context

In a paradigmatic examination of flight safety, one attempts to discover and elucidate patterns which are pervasive, typical and recurring, and have consequences relevant to the question of flight safety. In this chapter, I will articulate a *cognitive paradigm* which characterizes the way in which humans view and understand the world. The notions of *context* and *incongruity* will be developed as a fundamental aspect of this paradigm. Consequences of this paradigm to the question of flight safety will be drawn.

Context, Frameworks and Perception

The cornerstone of this cognitive paradigm is the notion of context. From its Latin etymology, context means "to weave together." Angeles defines it as:

> The sum total of meanings (associations, ideas, assumptions, preconceptions, etc.) that (a) are intimately related to a thing, (b) provide the origins for and (c) influence our attitudes, perspectives, judgments, and knowledge of that thing. [147]

Thus, *context* represents the "background" (with which we may not even be consciously aware) that affects what is perceived and how we interpret it. Errol Harris provides several examples of the effect of context on spatial and temporal perception. [148] In describing various experiments performed by Sir Frederick Bartlett, for example, he notes that when drawings of familiar objects were presented, subjects supplied appropriate details despite their actual inability to see them. A notice on which the actual writing could not be distinguished in the given time exposure, for example, was correctly interpreted by 80 percent of the observers as "Trespassers Will Be Prosecuted," when the notice was placed in the context of a closed gate. The suggestion of the correctly 'guessed' content of the notice arose out of the context within which it was placed and, thus, affected the detail of the perception. Of course that context could have led to the wrong 'guess' as well; the sign might have said: "Transients Welcome To Proceed." Harris concludes that:

> ...in all cases, the perceived object is an organic whole. Its character depends on its structure and the organization of its context, and it changes concomitantly with changes in its surroundings. What occupies the focus of attention is modified by alteration of its ...background, and *the present percept differs according to what came before it and what is expected to follow.* [149]

Think for a moment about the context surrounding the air traffic controller's response to MAC 40641 (see Chapter 1). When the MAC flight had radioed: "And Seattle, 40641 is level at ten;" it had been almost 4 minutes since the controller had communicated with the MAC flight, clearing it to "one-zero thousand;" he had had four exchanges with the Navy flight shortly after, clearing it to one-zero thousand also. Both flights would eventually be cleared to descend to five thousand. Even though the controller had heard "And Seattle, 40641..." and said "40641 maintain five thousand," it is obvious from his surprised and puzzled response to the Navy flight when it radioed two minutes later "Seattle Center, 28323 level at ten thousand" that he thought he had given instructions to the Navy flight to descend to five thousand -- still not registering to him that he gave *wrong* instructions to the MAC flight. In the context of the situation he had misperceived what actually had occurred and, perhaps, misinterpretd the incongruity ("28323 level at five?") as the Navy pilot not acting on his previous clearance. In any event, nowhere in the later transmissions is there any indication that he was aware that he ever gave the five thousand clearance to the MAC flight. In his mind, he filled in details from the context that were not there.

This phenomenon is characteristically human and very common. Undoubtedly, everyone has had similar experiences. Just recently, for example, my wife was giving a talk to her company division on Earth Day activities that might be feasible for people to do, such as walk to work. She said: "I often walk to work from my home in Camas." Well, we don't live in Camas, which is 10 miles away (hardly feasible for a daily walk to and from work); we live only 2 miles away in the opposite direction. It is fruitless to ask "why the mix-up;" but we can characterize the phenomenon by examining the context. Prior to making that statement (in fact, she was told later that she had made the same error twice) she had been talking about Denis Hayes, the father of the original 1970 Earth Day event, and mentioned that his home town was the nearby community of Camas, WA. After she had finished her talk, when a friend told her what she had said and that it obviously didn't make sense, she had no recollection whatsoever of making the error. Her response was: "Your kidding! Did I actually say that!?"

Such examples beg the question: Is this contextual "background" something in the external environment or internally supplied by the perceiver? Of course, it has to be both. The closed gate provided the external contextual cue as to what the sign likely said. But this only had conceptual meaning because in our everyday life we have experienced many such settings in which we saw signs on closed gates that actually did say: "Trespassers Will Be Prosecuted;" but few (likely none) which said: "Transients Welcome To Proceed."

Through experiences, we build in our minds a background of "concepts" which form a sort of mental "expectancy set" from which we view the world. That is, we tend to see what we expect to see. The notion of "concept" is fraught with potential difficulties [150], however, we can be relatively precise in our usage here by referring to Heath's characterization [151]. To have or to aquire a concept 'x' (I will substitute '[flight-safety]' as a specific example), Heath states, is:

> (a) to know the meaning of the word "[flight-safety];" (b) to be able to pick out or recognize a presented [instance or notion of flight-safety] (distinguish non-[flight safety notions], etc.), or again to be able to think of (have images or ideas of) [flight-safety] when [it is] not present; (c) to know the nature of [flight-safety], to have grasped or apprehended the properties (universals, essences, etc.) which characterize [flight-safety] and make [it] what [it is]. [152]

It is generally accepted, according to Heath, that the *concepts* involved themselves, when disentangled from *the having of them*, can be regarded as:

> ...essentially habits or capacities for the right use of words, or for the production of suitable conditioned responses, or for recognition, or for image formation... In all these cases the habit or propensity is generally thought of as acquired ...by some process of comparison, selection, and abstraction. Recurrent elements in experience are taken to engender, modify, and reinforce the disposition, which then operates in its turn as a principle for the ordering of subsequent experience, the guidance of action, or the control of thought and talk. ...Concepts in this sense, are still subjective and peculiar to the individual. It is assumed, however, that exposure to a common environment, plus the customary process of education and social attribution, will normally lead to a sharing of concepts and to the eventual acquisition of a standard repertory of concepts held in common by virtually all members of a given cultural or linguistic group. [153]

This conceptual background is the "internal context" supplied by the perceiver that facilitates one's perception processes. It reflects not only our past experiences and learning but our biases, beliefs and ideology. Thus, we have not only a cognitive nature of the "internal context," but its social nature as well. There is still the problem, though, of delineating which concepts are relevant and what context is relevant, and this can lead to much confusion and disagreement among parties engaged in a discussion of concepts such as flight-safety; that is, they likely will not share precisely the same cluster of concepts that, to them, contribute meaning to the word(s). Falling back on context, per se, does not adequately address the problem. People coming from different backgrounds supply different contexts, albeit, with some degree of overlap.

But even given the same backgrounds, there is still the problem of scope. Marc De Mey [154] points out that, although making an appeal to context for clarification and understanding incorporates higher level knowledge, thus making use of peripheral information which belongs to a larger whole, the problem with context is that it is so rich in possibilities it has no well defined boundary and thus has the potential of being all embracing. We can always enlarge it and one never knows if a sufficiently large portion of context has been checked. De Mey gives examples in communication where the essential context must include knowledge of social conventions and cultural rules if we hope to understand what is communicated by the sentences (not to mention the non-verbal cues that also affect the meaning of an uttered sentence). "The interpretation of the notion of context tends to expand until it embraces everything we know about a given subject." [155] This is certainly the nature of context as knowledge brought in by the information processor as part of the surroundings external to the individual, as well as knowledge accumulated from past experiences (cultural rules and norms, for example). Thus, it's relevancy to a given situation needs to be determined somewhat arbitrarily or subjectively (even subconsciously) by the individual on the basis (rightly or wrongly) of ones own "model of the world." [156] One's "expectancy set" is molded or structured by his or her "cognitive view" of the world -- that is, a *framework* of cognitive structures which one draws upon to filter the external contextual information. As such it directs our perception of reality. As De Mey puts it:

> In the cognitive view, *context* becomes something *supplied by the perceiver:* it is the knowledge he invokes to analyze the signal and to determine its meaning. It is, more precisely, the knowledge that permits him to look for and to detect very selectively those structural characteristics and more specific contextual elements which yield an interpretation of the message congruent with that knowledge. ...These cognitive structures embody a perceiver's knowledge by indicating what to discern, what to expect, what to say at a specific occasion. They constitute *world views* for typical situations specifying a particular universe in terms of the large amounts of prerequisite knowledge necessary for understanding even the most simple utterances. [157]

De Mey's central theme of the cognitive view relates to any sort of information we might process, whether it be a specific uterance ("And Seattle, 40641 is level at ten") or that of a scientist, say, studying some broad phenomenon (e.g. flight-safety). The information is "mediated by a *system of categories or concepts* which for the information processor constitutes a *representation* or *model* of his *world.*" [158] Only those features which are known through one's conceptual framework tend to be noticed and analyzed in so far as it seems necessary in order to check the match between the self-generated expectations and the perceived pattern. The world is not understood, however, from within one all-embracing unifying scheme. In the cognitive view, De Mey notes, our minds are populated with a multiplicity of world models which are triggered by external situations and in these situational contexts mental constructions are assembled in interaction with that situation as we attempt to perceive and interpret it. Further, these representational models vary widely in kind and internal structure. They may be internally rich and highly differentiated and can temporarily combine into a complex framework. Some may be alien to each other and thus "world views can be quite isolated and on their own -- sometimes separated from each other by staggering oceans of ignorance." [159]

World views are social entities as well as cognitive units. Both perception and communication depend on a world model. In fact, De Mey argues, perception and communication are one *whole* with the locus being the specific world view. In science, Thomas Kuhn has made this abundantly evident [160]. Even though there are still significant attempts to develop a "context free" language with which to understand science [161], it is Kuhn's *paradigm*-interpretation of scientific development that has best explained scientific perception and communication and has resolved the context boundary problem by observing that the context is supplied by the framework in the scientist's head, a framework that is shared by the other members of his or her particular scientific community.

This framework, the conceptual scheme of a specific aspect of "normal science," *is* the *Kuhnian-paradigm* -- "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" [162]. And [implicitly or explicitly] embedded in the "recognized scientific achievements" that the community of practitioners pattern their work after, are all the symbolic generalizations, metaphysical beliefs, analogies, and values that are characteristic of the model problems and solutions. But the existence of such a paradigm need not imply that a full formal rationalization of these elements even exist. They become tacit knowledge that is acquired through practice as understanding is passed on to others in the community through shared experiences with the same Kuhnian-paradigm [163]. As a cognitive and social unit, this paradigm represents the scientists' shared view of the world and it generates the expectations that drive his or her perceptual processes. In the context of normal scientific investigations, phenomena which are unexpected represent, in Kuhn's words, "anomalies" which constitute "puzzles" to be solved *within the framework one has learned to view the world over a long period of socialization and training within one's professional community.* And "normal science" is what the particular scientific community does on the whole. That is, their research is based upon past achievements with the prospect of extending the domain of applicability of the basic conceptual frameworks and of working them out in more detail to achieve greater precision and more accurate prediction and this, Kuhn notes, is essential to the development of science.

However, this is also where the community risks "tunnel-vision" through the restricted context provided by the communty's framework or Kuhnian-paradigms. Although the process of normal science is achieved...

> ...by extending the knowledge of those facts that the paradigm displays as particularly revealing, by increasing the extent of the match between those facts and the paradigm's predictions, and by further articulation of the paradigm itself, ...[it] seems an attempt to force nature into the preformed and relatively inflexible box that the paradigm supplies. No part of the aim of normal science is to call forth new sorts of phenomena; indeed those that will not fit the box are often not seen at all. ...Instead, normal scientific research is directed to the articulation of those phenomena and theories that the paradigm already supplies. [164]

As an example of the dominance of a specific Kuhnian-paradigm, consider how strongly the current thinking and models of cognitive psychologists hold to a rational linear framework for human intelligence processes. In the review article by Sternberg, which presents a consensual cognitive-scientific view of the nature of intelligence [165], the cognitive mechanism underlying intelligence is viewed from a "command and control" framework. Metacognitive processes plan, monitor and evaluate the cognitive or "non-executive" performance processes. This is the classic linear control model in which the executive processes direct and receive feedback from the task-performance processes. To illustrate, Sternberg states that the executive processes have the following structure:

RECOGNIZE PROBLEM -> DEFINE PROBLEM -> SELECT COGNITIVE PROCESSES -> CONSTRUCT PROBLEM-SOLVING STRATEGY -> SELECT MENTAL REPRESENTATION -> ALLOCATE COGNITIVE RESOURCES -> MONITOR SOLUTION

And the non-executive or cognitive processes that carry out the problem solving task have the following structure:

ENCODING -> INFERENCE -> MAPPING -> APPLICATION -> RESPONSE

Where encoding involves translating a stimulus into a mental representation; inference involves finding a rule that relates parts of the representation, for example in a verbal analogy problem, the first term of an analogy to the second term; mapping involves finding a rule relating common features of information, for example relating the two halves of an analogy; application involves applying the inferred relation, for example of the first half of the verbal analogy to the second half to arrive at a solution; and response is simply communicating the results.

Throughout this rational view, one can see the pervasive influence of rule-based logical positivist philosophy (see the discussion in Chapter 2) in this world view. The experiential nature of the human information processing phenomenon gets overlooked, if not ignored. The rule-based perspective is the focal point of much criticism, especially in such current areas as artificial intelligence [166]. Knowledge, for example, requires a background of practices and involvements. Dreyfus, in discussing levels of intelligence, notes that in a given task or decision domain only novices focus on features and rules; whereas, as one develops competence, emotion and involvement come into play through stored experiences and memories, experts having had enough success/failure memories that trigger what to do in a given situation. DeGreene, in writing about the impaired nature of human factors research, sees the situation in a similar way.

> Critics of cognition research, artificial intelligence, and expert systems contend that reasoning and intuitive expertise can never be mechanized; that rule following and analysis are characteristic of human *beginners*, not experts; that the failure of AI to develop theory and to live up to expectations after 40 years is attributable to a failure of rationalism, a failure that has also limited real advances in psychology, economics, and so on... [167]

It isn't that we should entirely toss out achievements that are modeled on "rationality," but that perhaps we have exhausted their potential as a Kuhnian-paradigm for the cognitive sciences, and yet we find it difficult to "break out" of this framework. We should put more emphasis on exploring other avenues, particularly ones that consider the profound question of context -- something that never enters into most of the studies that the rational model is based on.

To continue on the rationality controversy a bit further, in many circles, it has become well accepted since the seminal work of March and Simon [168] that we as human beings do not realize this "ideal" of absolute rationality. Rather, our thinking capacities and ability to achieve or even seek absolute rationality are limited, a state of affairs March and Simon referred to as *bounded rationality*. In actuality, we do not examine all existing cases or potential alternatives and seek the best representation, answer, or decision, basing judgment on all our experience. We tend to use rough estimates, rules of thumb, hunches or guesses -- *heuristics* that appear to be patterned and widely shared by people as we encounter everyday life. For example, one prominant heuristic is what these theorists call the "availability heuristic." That is, people tend to judge a situation in terms of the most readily available case, the one that comes to mind first. [169] Even though such heuristics have useful advantages such as preventing paralysis of decision making by agonizing over every possible contingency and cutting down on the "search time" to examine and rank all possible choices based on some criteria, they can get us into trouble since they may lead to the wrong action in given situations. Thus it appears, by the very relative nature of the phrase "bounded rationality," to be seen as something less than the ideal we should strive for -- absolute rationality. In our efforts to develop technological solutions we are oriented toward emphasizing the limits on our thinking capacity; viewing it solely as something lacking in our ability to achieve rationality, something that we must endeavor to overcome.

But Perrow [170] rejects this conclusion and expands our perspective on rationality further, in a way that links directly with context. He considers a dimension that he calls social and cultural rationality which is what most of us live by without thinking that much about it. Limits on cognitive rationality are recognized, but, social rationality holds that such limits are less consequential in accounting for poor choices than cognitive psychologists contend. The key theme, however, is that far from these limits being unfortunate, it is the very nature of this human phenomenon that provides considerable benefit in other respects. Heuristics, for example, facilitate social life by giving others a good idea of what we are likely to do in a given situation, since we appear to share these heuristics widely. We may not agree with the experts but joint action is facilitated. Heuristics are like regularized, checked-out intuitions. They slowly undergo revision as our experiences lead to corrections of hunches and rules of thumb without conscious effort. The sharing of heuristics comes from sharing similar social and cultural experiences, or similar contexts, as we engage life.

Another benefit is that even though all people have bounded rationalities, the joint world is enriched because their limits are not the same. Different people emphasize different skills and cognitions. They also see the world and its problems from different perspectives, e.g. quantitative versus one of social interaction. So not only do these limitations on rationality necessitate interdependence and promote social bonding, their differences facilitate new perspectives and solutions that no single individual is likely to have. They allow legitimately different values to enter and conflict.

The paradigmatic pattern of the cognitive framework that results in a sort of cognitive "tunnel vision" is not restricted to science. Loretta Graziano [171] has shown how our cognitive framework impacts discourse and decisions on public policy, often disposing it to systematic error. One reason this happens, she states, is because our minds become populated with simplified symbols that dispose individuals toward perceiving one subset of data about an issue and ignoring others. Designing a symbol, in fact, is an effective way to enhance perception of existing information. For example, the symbol "social safety net" points attention toward ongoing aspects of welfare programs rather than the aspects that are cut. Any serious student of marketing knows these pitfalls of human cognition and how they can be exploited to their advantage in "positioning" a product in the mind of the consumer [172].

> Positioning is what you do to the mind of the prospect. ...In general, the mind accepts only that which matches prior knowledge or experience. ...The basic approach of positioning is not to create something new and different. But to manipulate what's already up there in the mind. To retie the connections that already exist. [173]

This "image advertising" ploy intent on controlling public perception has pervasively penetrated political and public policy rhetoric, as well as the advertising rhetoric of the private firms. Graziano presents the example of the Department of Labor's unemployment rate as a widely-shared symbolic representation of the employment situation, which preframes our perception of a social problem and allows easy manipulation of that perception.

> Though this statistic only represents incidences of unemployment that conform to a restrictive definition, it tends to substitute in public cognitions for the overall situation. Individuals are thus less inclined to perceive and interpret the data that are left out of or conflict with this symbolic construct... President Reagan demonstrated an intuition for the public's symbol-reifying behavior when he hailed the rise of "full employment" from 4 percent to 6 or 8 percent unemployment. This would appear to be bad news, because "full employment" is the level of unemployment economists expected to persist at the end of a recession. But Reagan understood the public's stored meaning for this familiar symbol -- everything below this rate "doesn't count" (an artifact of the theory that cyclical unemployment is susceptible to policy instruments like aggregate demand management, while structural unemployment is not). Therefore, conceptually raising full employment to 8 percent automatically knocks 4 percent off the perceived level of unemployment. Because "structural unemployment" is not a familiar symbol, related data play a limited role in public cognitions, though by the President's own accounting it represents more than half of total unemployment. [174]

Likewise, Graziano notes, familiar frameworks are relied on for sorting and interpreting information which define problems that face us. "Our cognitive reliance on the 'poverty line' as a discrete threshold of family income has left our social service programs without a policy approach to the 'working poor'." In terms of international politics, for another example, we have become conditioned (until recently) to see social reality and issues of national security through a well structured framework.

> Our mania for structuring nations as "communist" or "free" overlooks most of the world -- the socialist democracies and the free market dictatorships; and it limits our leaders to two foreign policy alternatives: "soft" or "tough" on communism. [175]

Graham Allison's insightful analysis of the Cuban missile crisis [176]demonstrates how limited and faulty our options can be when our cognitive "world view" is so entrenched in one framework -- the rational actor model, in this case.

Thus far, this paradigm of human cognition has highlighted patterns that are part of our very nature as intelligent human beings. The flip side of these shortcomings of human cognition is, of course, the source of the human mind's efficiency. But what concerns us here is that complex causes and alternative solutions tend to get left out of the cognitive framework. As Graziano puts it, we have somewhat of a dilemma: widely-held expectations provide perceptual consensus of a problem and so facilitate action, regardless of its efficaciousness; a lack of widely-shared expectations, however, may obscure not only solutions, but entire problems. The public tends to rely on formally-trained experts to address the problems, including flight-safety, that face society. As we have seen above, even for these professionals, interpretive frameworks are resistant to revision; and because the public relies on experts to process new information, *their* cognitive limitations are introduced into widely-shared representations of reality. In the context of accidents, Perrow [177] also hammers on this point that the "framing" of the problem prejudges the problem and prejudices the answer. Experts can solve problems faster or better, but run higher risks than others of posing the wrong problem. For the expert, the problem is often defined to suit the methods.

Incongruity

In expanding one final aspect of this cognitive paradigm, consider now the pattern of our response to information that is incongruous with our conceptual framework. Incongruity represents a crucial problem, because, by its very nature, its perception represents a violation of expectation [178]. Earlier we noted that we tend to perceive what we are "prepared" to perceive through our conceptual framework, which implies a dominance of expectancy over stimulus. As long as perceptual expectancies are experienced as being confirmed, Bruner and Postman state, they continue to mold perceptual organization in a self-sustaining fashion. That is, the directive processes in the perceptually "prepared" individual operate to organize the perceptual field in such a way as to maximize percepts relevant to current needs and expectations, and to minimize percepts inimical to such needs and expectations. Their contention is that for as long as possible and by whatever means available, the individual will ward off the perception of the unexpected, those things which do not fit his prevailing expectancy set.

But this reaction is obviously not the whole picture. After all, we know that lots of incongruities do get perceived. Bruner and Postman designed and ran an experiment to reveal the pattern which characterizes the perception of incongruity and how it is dealt with. The experiment was done with subjects viewing a random series of playing cards at different exposure lengths. Most cards were normal but some of the cards in the series were made with incongruous information, with the color and suit reversed. For example, the cards contained such anomalies as a black three of hearts, red six of spades, etc. After each exposure the subject described what he or she had seen and the experimental run was terminated by two successively correct descriptions. The context of the experiment was supplied by the subjects common knowledge of playing cards; e.g. hearts and diamonds are red, spades and clubs are black. They were not aware that information would be displayed in the experiment that was incongruous with this normal playing card framework.

Cards were identified by virtually all subjects at very short exposure times[47]. Normal cards were usually identified correctly, however, at the same exposures incongruous cards were identified as normal cards with no awareness of the incongruity. Once the observer had experienced correct recognition of incongruous cards the performance on such cards improved considerably. This was consistent with the notion that when one has experienced an incongruity often enough, it ceases to violate expectancy and hence ceases to be incongruous. This was quite apart from skill practice. Prior experience with exposures of normal cards did not lead to better recognition performance with incongruous cards. Thus it was the *experience* with incongruity that was effective in modifying the expectancy set of the subject to prepare him or her for the incongruity.

Bruner and Postman also characterized the nature of the reactions to the perception of an incongruity as the subjects were allowed longer and longer exposures until it was finally recognized. Quantitatively, there was a highly significant four-fold increase in the threshold time for correctly recognizing incongruous cards over normal cards. Qualitatively, they discovered four kinds of reaction to the rapidly presented incongruities which characterize the manner in which subjects dealt with or coped with incongruity per se.

The first and most prevalent of these is what Bruner and Postman called the *dominance* reaction, which was almost universal among the subjects. It consists, essentially, of a "perceptual denial," in their words, of the incongruous elements in the stimulus pattern. That is, the subjects had no awareness of any incongruity and believed they had correctly identified the cards. The perceptual resultant conforms with past expectations about the "normal" nature of playing cards, which is the internal "playing card context" supplied by the subjects' minds. Such dominance reactions occurred with equal frequency to trick black or red cards. The subjects would either organize the field in terms of suit, e.g. hearts seens as red regardless of their stimulus color; or the field would be organized in terms of color, e.g. a red card seen as a heart or diamond regardless of its true suit. An incongruous stimulus was rendered congruent with expectancy by the operation of either expectant form dominance, e.g. the red six of spades seen as the six of spades, or color dominance, e.g. the red six of spades seen as the six of hearts.

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47 See the article for statistical details.

A second kind of reaction to the incongruity reflected a "perceptual middle ground" between the expectancy and the stimulus contradicting the expectancy, and they termed this the *compromise* reaction. A subject experiencing this type of reaction perceives a compromise object which embodies elements of both the expected attribute and the attribute provided by the sense stimulation. They reported examples such as: the red six of spades seen as either the purple six of hearts or the purple six of spades; the black four of hearts reported as a "grayish" four of spades; or the red six of clubs seen as the six of clubs illuminated by red light.

A third reaction was termed *disruption*. In this case the subject consciously experiences a gross failure to achieve a perceptual organization at a level of coherence and efficiency normally attained by him at a given exposure level. The subject fails to confirm any of his repertory of expectancies; that is, he is perceptually confused and is aware of this confusion, losing confidence in his ability to understand his perceptual experience. The authors found that disruption usually follows upon a period in which the subject has failed to resolve the stimulus in terms of his available perceptual expectations. A typical reaction is one of frustration, such as: "I don't know what the hell it is now, not even for sure whether it's a playing card." The disruption could even be displaced away from the actual incongruity; some subjects, for example, showed disruptive uncertainty about the number of pips present or the number in the corner, even after they had already perceived it correctly.

Finally, there is *recognition* of incongruity. But this reaction in the perception of incongruous stimuli is temporarily thwarted and exhibits characteristics which are generally not observable in the recognition of more conventional stimuli that are congruous with expectations. There is often an emergence of a "sense of wrongness" which leads to a succussful unmasking of the incongruous stimuli by having the effect of making the subject give up his previous expectation about the nature of the stimulus.

> The subject may either, even while "dominance" and "compromise" responses are continuing, suddenly or gradually begin to report that there is something wrong. It is not infrequent after such a report to witness the onset of perceptual disruption. ...Occassionally, ...the sense of wrongness may become focused upon a rather tangential, but, in point of fact, correct aspect of the incongruous stimuli and in so doing lead to a successful unmasking. These subjects, prior to correct recognition, all reported that the *position* of the pips on the card was "wrong." All these responses were given either to spades printed in red or hearts printed in black at a time when the subject was calling the black hearts "spades" or the red spades "hearts." [179]

Bruner and Postmand report that the process of recognition is characterized by slowly overcoming a resistance to change in the expectation. The recognition of incongruity occurs after an unsuccessful period of "trial-and-check," often accompanied by a sense of uncertainty or wrongness, which all point to a gradual weakening of previously held expectations before the "shock of recognition" can occur -- a final reaction characterized by such statements as: "Good Lord! What have I been saying? That's a *red* six of spades!"

Mindlock: Nemesis of the Framework

One of the most serious difficulties in coping with incongruity relates also to the availability heuristic that was mentioned earlier. Faced with ambiguity, the individual rapidly favors one available interpretation and is then loath to part with it. Cognitive psychologists call this "confirmation bias." Several studies have shown that preliminary conclusions formed on the basis of relatively impoverished early data interfere with the later interpretation of additional information. [180] It works as a selective process that favors items relevant to the presently held view. When we grab onto something we initially think is correct, we encounter the almost unavoidable result where we tend to fill in details from our expectancy set (details that may or may not exist in actuality). That perpetuates not only our misperception, but our ability to realize that an alternative framework might exist. Bruner and Postman conclude that:

> Perhaps the greatest single barrier to the recognition of incongruous stimuli is the tendency for perceptual hypotheses to fixate after receiving a minimum of confirmation. As we have noted, some of our subjects persisted up to 1000 milliseconds in giving dominance responses to incongruous stimuli. Once there had occurred in these cases a partial confirmation of the hypothesis that the card in the tachistoscope[48] was a black club or a black spade, it seemed that nothing could change the subject's report. ...[For an extreme example,] there were six instances in which subjects persisted in a color or form dominance response for over 50 exposures up to 1000 milliseconds, finally failing to recognize the card correctly. [181]

Such fixation tendencies, they believe, are the chief block to perceptual learning and present a problem which is exacerbated by the environmental and emotional context the subject is expected to perform under. Citing one of their earlier studies on the effects of stress on perception [182], the authors point out that:

48 The machine used to present cards at a specified exposure time.

> Perceptual recklessness often resulted when a subject had to work under difficulties -- the formation and fixation of "premature" and incorrect perceptual hypotheses. It would appear, indeed, that working in incongruous situations where partial confirmation of expectancy can occur (the form of a spade is not so different from that of a heart, even if the colors are) has the same effect of inducing premature fixation. [183]

This implications for the flight environment are obvious. We have seen in the MAC 40641 situation where both the air crew and the controller did not deal effectively with incongruous information, even under light load conditions. Heavy workload and/or crisis situations are part of the job, as well.

Consider now some broader implications of this incongruity response pattern. Citing historical examples in science, Thomas Kuhn draws strong parallels from the Bruner and Postman study, using it in fact, as a simple paradigm[49] for the process of scientific discovery.

> In science, as in the playing card experiment, novelty emerges only with difficulty, manifested by resistance, against a background provided by expectation. Initially, only the anticipated and usual are experienced even under circumstances where anomaly is later to be observed. Further acquaintance, however, does result in awareness of something wrong or does relate the effect to something that has gone wrong before. That awareness of anomaly opens a period in which conceptual categories are adjusted until the initially anomalous has become the anticipated. At this point the discovery has been completed.

The perceptual fixation accounts for the stability of a [Kuhnian-] paradigm. Eventually, anomalies can be seen and adjusted for but it is extremely difficult to shake off entirely the mental expectancy set or framework the Kuhnian-paradigm imposes. That is why it takes a crisis in the field -- an accumulation of anomalies and significant problems that the current paradigm fails to explain -- in order for the community to even consider an alternative paradigm. The dominant paradigm becomes blurred and the field must be reconstructed by placing old observations, data and problems in "a new system of relations with one another by giving them a different framework" [184]. What some scientists may perceive from the changed framework provided by the new paradigm is incongruous to those who hold to the framework of the old paradigm. So disparate can the reactions be that, in Kuhn's strong words, there is often no rational way of measuring or judging them comparatively. That is, the two frameworks are *incommensurable*. Either you see things from the new framework or you don't. The members of the community become

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49 In the sense of a pattern; although Kuhn referred to it as a "schema" since he already coopted a specific technical use for the generic term paradigm, as we have discussed earlier.

divided by which framework they "buy into." There exists no higher-level framework which can be used as a basis to rationally adjudicate the differences and conversion must come primarily through emotional means like persuasion.

However extreme Kuhn's notion of this intellectual abyss between frameworks seems, even his serious critics acknowledge the blinding impact of the framework. One of Kuhn's long-time critics, Karl Popper, in an anthology specifically focused on changes in science [185], has presented a recent argument summarizing his long held views on the framework and science. His main concern is the problem of relativism, the doctrine as he sees it, that our understanding of "truth" (what ever that is) is "relative to our intellectual background or framework: that it may change from one framework to another" and that this affects our ability to communicate understanding across social or historical boundaries [186]. He does not believe this is the case in what one calls science and he labels it a *myth,* stated in one sentence as:

> A rational and fruitful discussion is impossible unless the participants share a common framework of basic assumptions or, at least, unless they have agreed on such a framework for the purpose of the discussion. [187]

But his argument boils down to one of degree and just what the nature of rational discussion and science is (or should be). He focuses on debunking Kuhn's notion of incommensurability as an aspect of science, insisting that in science we must demand that new frameworks and theories *not* be incommensurable; the barriers are not absolute. But, he agrees that frameworks are barriers, even "prisons," speaking metaphorically.

> Although I contend that it is a vast exaggeration to say that a fruitful discussion is *impossible* unless the participants share a common framework, I am very ready to admit that a discussion among participants who do not share a common framework may be *difficult.* A discussion will also be difficult if the frameworks have little in common, and it will be the easier the greater the overlap between the frameworks. [188]

He points out the importance of framework awareness in guarding against the "intellectual prison ...in which one might get stuck unconsciously, at any moment of one's life." Or worse yet, the addiction to any particular framework which, in his own frustrating experience dealing with people from different schools of psychology or sociology, seems to make the wall impenetrable indeed.

> It was during the great and heated discussions after the First World War that I found out how difficult is was to get anywhere with people living in a closed framework. ...None of them could ever be shaken in his adopted view of the world. Every argument against their framework was by them so interpreted as to fit into it; and if this turned out to be difficult, then it was always possible to psychoanalyse or socioanalyse the arguer: criticism of Marxian ideas was due to class prejudice, criticism of Freudian ideas was due to repression, and criticism of Adlerian ideas was due to the urge to prove your superiority, and urge which

> was due to an attempt to compensate for a feeling of inferiority. ...The Marxist literally sees class struggle everywhere; thus he believes that only those who deliberately shut their eyes can fail to see it. The Freudian sees everywhere repression and sublimation; the Adlerian sees how feelings of inferiority express themselves in every action and every utterance, whether it is an utterance of inferiority or superiority. [189]

Popper also acknowledges that all observations are under the influence of ones framework; but that, whatever problems this presents, we can overcome them for "it is the method of science, of critical discussion, which makes it possible for us to transcend not only our culturally acquired but even our inborn frameworks." [190] The differences between Popper and Kuhn on the notion of the framework may boil down more to the difference between Kuhn's descriptive focus, on the one hand, on how science *is* practiced (in his view), and the normative perspective of Popper, on the other, of how science *should* be practiced and his disgust with the negative implications of the framework, at least in his interpretation of Kuhn's view.

Popper refers ot the leaps between rational periods of science conducted within a framework -- periods which he says the proponents of the view of the myth of the framework are describing as periods of closed or authoritarian science. He refers to the "almost irrational leap" from one framework to another as "comparable to a religious conversion."

> No doubt there are such irrational leaps, such conversions, as described. No doubt there are even scientists who just follow the lead of others, or give way to social pressure, and accept a new theory as a new faith because the experts, the authorities, have accepted it. I admit, regretfully, that there are fashions in science, and that there is also social pressure. ...I even admit that the day may come when the social community of scientists will consist mainly or exclusively of scientists who uncritically accept a ruling dogma. They will normally be swayed by fashions; they will accept a theory because it is the latest cry, and because they fear to be regarded as laggards. ...I assert, however, that this will be the end of science as we know it. [191]

Even though the concept of the framework is fraught with such controversy, the impact of the cognitive framework on the way we view the world is something we must face directly in conceptualizing and dealing with flight safety.

Summary of the Cognitive Paradigm

The essence of the cognitive paradigm is the notion of cognitive framework as the dominant pattern that explains how we organize, perceive and interprete reality. It builds upon the notion of context. *Context* is the "background texture" of reality into which a thing, phenomena, event or communication is "weaved." It is all those things, meanings, conditions and so forth that are related to something under consideration; the sum total of everything that influences what we perceive about something, how we interprete it, our attitudes toward it, our judgments and so forth. It consists of tangible things and intangible things, it is both externally supplied by the environment or the structure and dynamics of a situation, the coalescing of a particular set of events perhaps, and internally supplied from our background of concepts which reflect past experience, learning, biases, beliefs, ideology and social relationships. All these things we bring to bear on our perceptions, interpretations, actions and decisions. Context can be thought of as the metaphorical "stage" or "setting," if you will, upon which the "performance" takes place.

Contexts can be so rich and encompassing, however, that we need a way of organizing the contextual information so we can draw upon that which is appropriate to a given situation. This is the idea of a *cognitive framework*. It is an abstract notion of the bringing together, linking or clustering of concepts into an "expectancy set" that forms a representation or model of the world in our mind. We can think of the system of categories and concepts as a cognitive structure which forms the basis from which we very selectively detect and perceive reality. We do not have one all embracing such structure or framework but a multiplicity of mental contructs triggered and linked at any given moment by external or situational contexts. The framework filters the multitude of contextual elements and their structural characteristics in a way that yields a message congruent with our world view. This provides for rapid and efficient perception without having to process all the detail.

Frameworks are not only cognitive structures contained within one's mind, they are social entities as well. Frameworks are shared by social units or groups -- "communities," in one sense, of professionals or others (people of a particular political persuasion, perhaps) who tend to exchange ideas and perspectives through various forms of communication. Frameworks are developed over long periods of socialization, training, the sharing of experiences, etc., among those who choose to participate in the community. As a corollary, communication among different communities who do not share the same framework is made more difficult. They simply don't see the world the same way.

The cognitive framework which helps us perceive and understand the world that we engage carries with it some unavoidable results. Among these are *tunnel vision* and *mindlock* (or confirmation bias). Only those features of phenomena which are known through one's cognitive framework tend to be perceived. Further, after we grab onto something in our minds that we initially think is correct, we tend to fill in details from our expectancy set whether or not they actually are part of the thing we are perceiving.

Consequently, humans have difficulty perceiving *incongruities*. Our expectations dominate our perceptions and when a phenomenon presents something -- especially in a subtle way -- that is incongruous with our expectations it tends not to be readily perceived. This "perceptual recklessness" is exacerbated by the environmental and emotional context. If the environment is complex or rapidly changing as in the precursor to an emergency, for example, it is more difficult to perceive even that an incongruity exists. And if it is perceived that "something must be wrong here" or "something is different," then it is difficult to detemine what that something is. On the other hand if the environment is very familiar and routine, you know it so well that you have difficulty perceiving minor incongruities because most of your perception of the familiar environment comes from the details filled in from your expectancy set.

Finally, these problems are compounded under *conditions of emotional stress* such as that caused by conflict, preoccupation with troubling situations, or simply sleep deprivation.

Experience helps to counter some of these effects. That is, once incongruities of one form or another have been experienced and (finally) recognized, they are no longer incongruities and they get tucked away in the framework. Now, if they are experienced only rarely, the path to them will not be as "well worn" as other things that are experienced more often. In fact, you still may find it difficult to *believe* you perceive the incongruity even when it's there the next time, because it does not attain a very dominant place in the framework. What can give it a more prominant position in the cognitive framework is when it is attached to some emotional experience or reaction -- positive or negative. I will tie this in with some examples later on.

In summary then, the more varied and rich our experience base, the greater capability our cognitive framework will have in perceiving phenomena more accurately -- or at a minimum, the greater awareness we will have of its limitations and thus know when and how to compensate for them.

Implications for Aviation Safety

There are two areas for which the cognitive paradigm has major implications, one narrow in focus and one broad. The first one relates to its impact on operator performance. Highly trained and skilled pilots and controllers view the world from a framework that serves them extremely well, yet often they deal with incongruous information under a variety of conditions. Can we fashion better ways to cope with this reality? Is it something that can be "designed out" of the human components of the aviation system, through technological fixes, if you will?

The broader implication of this cognitive paradigm is the way we actually view flight safety, how we analyze it in terms of accident investigations, the way we perceive the human element and how that directs prevention efforts and technology in the cockpit and on the ground. We can see how different people coming from different backgrounds, interests and social groups can hold to different concepts of "flight-safety" (a term with a surface appearance of common understanding), the factors that influence and characterize it and, in particular, the way in which flight-safety problems are defined.

Consider another example of the linear rational perspective that dominates the way we tend to frame problems of human cognition, this one as it relates to the element of human error in human-machine systems. A highly acknowledged and widely cited article by William Rouse and Sandra Rouse [192] examines the literature on human error and proposes a methodology for its analysis and classification; the framework is used for identification of possible causes and factors that contribute to the occurrence of errors. Their framework is based on a conceptual model of operator tasks as follows:

OBSERVATION OF SYSTEM STATE -> IDENTIFICATION OF PROBLEM -> CHOICE OF HYPOTHESIS ->
TESTING OF HYPOTHESIS -> CHOICE OF GOAL -> CHOICE OF PROCEDURE ->
EXECUTION OF PROCEDURE

The six steps (the decision as to whether or not a problem is evident is excluded) are used as general categories for human error classification and specific categories are then derived under each general category.

> General categories discriminate among the behavioral processes within which human error occurs. Specific categories define the particular characteristics of erroneous decisions or actions. In a loose sense, the general categories can be viewed as being behavior oriented while the specific categories are more task-oriented. [193]

Human errors are then defined as failures (omission and commission) to adhere correctly to this rational process model of the operator's tasks (relevant to the particular domain of study). The viewpoint is one which sees errors as the result of a mismatch between human abilities and the demands of the task and environment; mismatches which can then be isolated and identified. The approach is intended to get at the causes of errors.

> The causal approach to characterizing human error is based on the premise that errors are seldom random and, in fact, can be traced to causes and contributing factors which, once isolated, can perhaps be eliminated or at least ameliorated. Thus the causal approach can be useful for evaluating and subsequently modifying system designs and training programs. [194]

The Rouses' study was extensive and fits well with the way we think of managing technological systems. It is behavioristic, linear, and rational. Such a world view we might call *absolute rationality* and it is shared by many disciplines such as economics, engineering, operations research and systems analysis, for example, in the way they define problems and determine appropriate or acceptable solutions. If one approaches problems of flight-safety from a perspective based on a model of the human as a rational decision maker, such as that presented by the Rouses in their analysis of human error, one tends to approach the goal of improving flight-safety by finding ways to help the human become a more rational decision-maker and thus try to eliminate (or substantially reduce) human error by, perhaps, building in more "intelligent" technology to help the human operator at various points in the rational decision process. Granted, this may be an effective approach, even the *most* effective approach we have yet conceived. The point is, however, that the "framing" of the problem prejudges it and biases the approach to solving the problem. Engineers, and I am one, come from educational backgrounds which have developed a large repertoire of technical concepts whose essence is rationality and a high degree of skill in applying these concepts to problems. It is natural for them to conceive problems as opportunities for a "rational" technological fix. But what does it leave out, if anything?

Now step back for a moment and reflect back upon the nature of the C-141 accident as I have described it thus far. We have a rather routine, favorable environment (light traffic load, no severe weather) air traffic control situation, simultaneously with an obvious misperception on the part of the controller, and the aircraft crews of the respective controlled airplanes obediently following the controller's directives. All individuals involved were qualified professionals and no one was under the influence of any mind altering substance. The explanation and our understanding of this aviation disaster seems rather apparent and perhaps as straightforward as the FAA's summary of the situation: "...caused by human error by an air traffic controller who inadvertently radioed descend instructions to the Air Force airplane instead of a Navy aircraft he was also controlling" (see Chapter 1). Can there be any question of culpability? It does not take a background in cognitive psychology to understand this as a case of human error and we should certainly focus attention on helping these operators recognize and/or avoid such mental errors. This is one perspective on flight-safety and it is certainly influenced by the *context* of this accident as well as the *concepts* we might hold about aviation accidents and human error from past experiences, education and the professional communities to which we belong. But what is the *scope of the context* that is relevant to this situation? Would it be defined differently by people in the FAA from those in the Air Force and accident investigation experts, who perhaps have training in cognitive psychology? Are there organizational or even larger meta-system implications; perhaps even incongruous goals to consider? From which *concepts of safety and accidents* should we view this tragic situation? So far we have some proximal causes; how extensive should our examination of the context be? What is the nature of "flight-safety?"

Are we locked into a framework which blinds us to contextual factors that cannot be ferreted out in the traditional apodeictic "cause-and-effect" sense? For example, if the thrust of human factors engineering is "to develop equipment that is most compatible with the abilities and performance characteristics of equipment operators" [195]; to study "the variables involved in the relationship between the capabilities and limitations of men [sic] and the characteristics of machines ...and apply these variables to the design and evaluation of man-machine systems" [196]; it is given that the context of the knowledge brought to bear is that of a complex physical (electro-/mechanical/chemical/software) system containing at least one imperfect and fallible human being. In this context, then the entire focus becomes one of technological fixes, whether it be human-machine interfaces, mechanized "assistants," workload and/or information management systems or whatever, to address the fallibility of the human element and/or optimize some overall measure of system performance by enhancing the human's unique contribution to the operation of the system. Of course this work is important and needed. However, if it is the only *framework* from which we approach such troubling phenomena as system accidents we are certainly blinded by a prejudged structuring of the problem and we then bring to bear on it only those concepts within the framework and (Kuhnian-)paradigms of that particular professional community. Higher level system phenomena do not get considered (see Bella's article on "Star Wars" technology for a sobering example [197]), nor do sociological phenomena, in particular organizational phenomena. Charles Perrow examines the organizational context, for example, of human factors engineering and how the organization restricts the influence of human factors engineers as well as their perceptions. [198] Perrow looks at how organizational structure affects the design of equipment and how new and sophisticated equipment reinforces existing organizational structures and reproduces them in new settings. Elsewhere he gives an extensive account of how organizational structures and broad scale system characteristics, as well as human-machine interfaces, may actually contribute to accidents. [199]

David Bella describes how engineers and scientists, when they serve as mere "functionaries" of the organization (each does a good job in his or her particular assignment but has no professional involvement beyond that) become captives to a distorted organizational perspective; they see the world from an organizational context which has the self serving adaptive behavior of minimizing disruptions through the systematic distortion of information. [200] For example, the FAA, ALPA (Airline Pilot's Association), ATA (Air Transport Association) and other industry trade associations, commercial carriers, the U.S. Air Force all are organizations with different purposes and, consequently, have different perspectives on flight-safety. Each would have a tendency of selecting information favorable to its interests and discounting information that causes disruptions, thus over time perspectives on flight-safety become distorted by the framework the individuals of each organization are operating from. Bella gives a lucid example of how this happened with NASA and the space shuttle Challenger disaster and we will explore this a bit further later on.

It is my contention that such contextual patterns go unnoticed, or are rejected out of hand as insignificant, and that proponents of such views are scoffed at, if not scorned, *because of* the mindset our existing flight-safety framework imposes on us.

> One of the things a scientific community acquires with a [Kuhnian-]paradigm is a criterion for choosing problems that, while the paradigm is taken for granted, can be assumed to have solutions. ...[Such a framework] can, for that matter, even insulate the community from those socially important problems that are not reducible to the ...form [required by the paradigm], because they cannot be stated in terms of the conceptual and instrumental tools the paradigm supplies. [201]

The next three chapters present three additional paradigms which articulate significant patterns that go beyond our traditional apodeictic approach to the explanation of flight safety.

Chapter 5

The Paradigm of Normal Accidents

Routine accident investigations are apodeictic in the sense that they seek a definitive determination, through cause-and-effect explanation, of the "primary cause" or "sequence of events" that resulted in the accident. The analysis is proximal in nature, following the specific chain of cause-and-effect logical relationships that relate to the specific accident. Through such routine investigations we may discover *post facto* certain failures and interactions that were not or could not have been expected or thought of prior to their occurrence. After the failures and their interactions are experienced through the occurrence of an accident we then see possible technological fixes that might prevent that specific case in the future; but, we have no way of assuring ourselves that some other unthought of set of circumstances may not result in another catastrophe. Such insights are incomplete, at best, and may even lead to fixes that don't solve the problem.[50]

Many things that we might wish to know about exhibit a complexity that is impenetrable. Systems researchers often approach complex system analysis and design questions by building a model of the physical system in order to better understand the complexities of its behavior. In many cases much insight is gained; however, we have already noted some of the inadequacies of this approach in Chapter 2. Another approach is to accept the complexity as given and gain insight about it by describing and characterizing it. This is what Charles Perrow has done for accident research in the paradigm he has developed of "normal accidents." [202]

Normal Accidents: A Profile

There are characteristics of high-risk technologies that suggest that no matter how effective conventional safety devices are, there is a form of accident that is inevitable. Perrow labels these *normal accidents* and their inevitability has to do with

50 Of course, a history of such events, analyses and fixes can provide for learning and evolutionary system improvement.

the way failures can interact and the way complex systems are tied together. Perrow has researched a multitude of high technology systems and associated accidents including nuclear power generation, petrochemical plants, marine transportation systems, health-care systems, and aircraft and airways, to name a few. His research has revealed a pattern of integral system characteristics -- namely, *interactive complexity* and *tight coupling* -- that inevitably will produce an accident through multiple and unexpected interactions of component failures. The term "normal accident" (or system accident, more formally) does not mean they are common in a frequency of occurrence sense; in fact, they are uncommon, even rare, but can have catastrophic potential. They are "normal" in the sense that it is an inherent property of the system for such interactions to occur on occasion. [203] Perrow states the basic argument very simply:

> We start with a plant, airplane, ship, biology laboratory, or other setting with a lot of components (parts, procedures, operators). Then we need two or more failures among components that interact in some unexpected way. No one dreamed that when X failed, Y would also be out of order and the two failures would interact so as to both start a fire and silence the fire alarm. Furthermore, no one can figure out the interaction at the time and thus know what to do. The problem is just something that never occurred to the designers. Next time they will put in an extra alarm system and a fire suppressor, but who knows, that might just allow three more unexpected interactions among inevitable failures. This interacting tendency is a characteristic of a system, not of a part or an operator; we will call it the "interactive complexity" of the system.
>
> ...But suppose the system is also "tightly coupled," that is, processes happen very fast and can't be turned off, the failed parts cannot be isolated from other parts, or there is no other way to keep the production going safely. Then recovery from the initial disturbance is not possible; it will spread quickly and irretrievably for at least some time. Indeed, operator action or the safety systems may make it worse, since for a time it is not known what the problem really is. [204]

Perrow has reviewed hundreds of accident investigation reports and has found the traditional "primary cause" explanation of most investigations to be grossly lacking. For example, consider the following general categories from which a primary cause might be drawn: 1. Human error; 2. Mechanical failure; 3. The environment; 4. Design of the system; 5. Procedures used. Now think of a very complex, tightly coupled system -- that of nuclear power generation. Perrow found that the President's Commission to Investigate the Accident at Three Mile Island[51] chose #1 and blamed virtually everyone, but primarily the operators for failing to properly diagnose the problem. The builders blamed only the operators. The officials who ran the TMI plant blamed

51 He was asked to contribute an organizational analysis for this effort that "threatened to be an entirely engineering-oriented investigation."

mechanical failure (faulty valve). And finally, an outside group of experts who studied the control room for the Nuclear Regulatory Commission blamed the design of the system. [205]

Taking more of a paradigmatic view of the accident, Perrow notes that TMI had multiple failures that interacted in unforeseen and temporarily incomprehensible ways and thus TMI represents a classic paradigm of a "normal" or "system" accident.[52] It is Perrow's contention that "none of the above" would be the best choice for the "cause" of the accident since *the accident was a manifistation of inherent system characteristics.* Following an illustrative hypothetical example, he summarizes what is so often typical of system accidents like TMI.

> The cause of the accident is to be found in the complexity of the system. That is, each of the failures -- design, equipment, operators, procedures, or environment -- was trivial by itself. Such failures are expected to occur since nothing is perfect, and we normally take little notice of them. ...Though, the failures were trivial in themselves, and each one had a backup system, or redundant path to tread if the main one were blocked, the failures became serious when they interacted. It is the *interaction* of the multiple failures that explains the accident. ...When we have interactive systems that are also tightly coupled, it is "normal" for them to have this kind of accident, even though it is infrequent. It is normal not in the sense of being frequent or being expected -- indeed, neither is true, which is why we were so baffled by what went wrong. It is normal in the sense that it is an inherent property of the system to occassionally experience this interaction. ...What we don't expect is for all of these events to come together at once. [206]

High technology systems have become so complex that we cannot possibly foresee all of the possible failures and their interactions. Further, when they do happen we often cannot even understand what is happening at the time of the accident. The cognitive paradigm is ever with us (see Chapter 3).

> In complex industrial space and military systems, the normal accident generally (not always) means that the interactions are not only unexpected, but are *incomprehensible* for some critical period of time. In part this is because in these human-machine systems the interactions literally cannot be seen. In part it is because, even if they are seen, they are not believed. ...Seeing is not necessarily believing; sometimes, we must believe before we can see. [207]

Three Mile Island was the worst nuclear disaster experienced thus far (in the U.S.). Perrow's involvement with analyzing nuclear systems led him to conclude (in 1984) that:

> We have not had more serious accidents of the scope of Three Mile Island simply because we have not given them enough time to appear. But the ingredients for such accidents are there, and unless we are very lucky, one or more will appear in the next decade and breach containment. [In fact,] I would expect a worse accident than TMI in ten years -- one that will kill and contaminate. ...Despite glaring failures of the nuclear power industry, it is clear

52 Perrow does not use the term paradigm. Nonetheless, as we have developed the meaning of the term, it is precisely Perrow's approach to his examination of "normal accidents."

> that its design, construction, and operating problems do not, in themselves, constitute the cause of system accidents. It is instead the potential for unexpected interactions of small failures in that system that makes it prone to system accidents. [208]

It is dramatically ironic that these points have been borne out with the Chernobyl disaster just two years later in April 1986. This catastrophe is also a paradigm of Perrow's normal accident, as well as a cognitive paradigm of the context and incongruity problem. The disaster was related to a "purely electrotechnical" test for which preparations were inadequate, but which was thought to have no impact on nuclear safety. Zhores Medvedev writes:

> The scene was thus set, but, as will be clear from what follows, the accident would not have occurred without a wide range of other interrelated problems and major violations. Although this depiction of the first crucial error is accurate, it was caused not just by an oversight on the part of the Chernobyl plant managers, but by the way in which nuclear energy is administered in the Soviet Union. [209]

In the case of Chernobyl we again have an accident investigation, reviewed by experts, who avoided examination of the broader contextual issues, focusing apodeictically on proximal cause and effect and laying principal blame on the operators. We might expect this, perhaps, from a closed society such as the Soviet Union but the Soviet report was reviewed and probed by nuclear experts from 62 different countries at a post accident review meeting in Vienna.

> The nuclear energy experts who took part in the discussion did not ask certain important questions and seemed satisfied with some inadequate answers given by the Soviet delegation. ...The Soviet report was intent on minimizing problems of reactor design and placing the blame for the accident exclusively on the operators. There is no reason to doubt the correctness of the facts offered or the sequence of events. The participants in the post-accident meeting were interested in technical aspects that might be relevant to the nuclear reactors in their own countries. ...But if the post-accident meeting had been a more open enquiry in which not only nuclear energy experts had participated, but also economists, planners, ecologists and experienced journalists, the picture of the accident which emerged might have contained details that explained both the sequence of errors and also the causes of the errors. [210]

These nuclear examples of Perrow's normal accident paradigm are presented here because, in Perrow's view, nuclear plants represent the virtual extreme of complexly interactive and tightly coupled systems. For them, and for most of the systems he considers which exhibit some similar degree of complexity and coupling characteristics,

> ...neither better organization nor technological innovations appear to make them any less prone to system accidents. In fact, these systems require organizational structures that have large internal contradictions, and technological fixes that only increase interactive complexity and tighten the coupling; they become still more prone to certain kinds of accidents. [211]

Some systems, however, such as manufacturing and air traffic control, have managed to reduce interactive complexity and tight coupling through better organization and "technological fixes." Perrow considers the airways system to have moderately complex interactions and to be rather tightly coupled. Aircraft and flying itself, however, he places considerably higher on complexity and with very tight coupling. Although the airways system is put forth as a model of a system in which profound improvements have been made to reduce the potential for system accidents, it still exhibits those characteristics that can result in such system catastrophies. Before considering the implications of this paradigm on flying in more detail, however, it will be helpful to develop the terminology and concepts of the normal accident paradigm a bit further.

Terms and Definitions

Following Perrow [212] a hierarchical structure for complex systems is delineated that is useful in differentiating types of failures as well as system characteristics which have implications for their potential for failure, and recovery from failure. This structure allows one to focus on an explanation based upon system characteristics themselves, rather than on the conventional item analysis and errors that are made by owners, designers, manufacturers, and operators in the designing, building and running of these systems. In his comparative examination of system accidents, Perrow has found that:

> Something more basic and important contributes to the failure of systems. ...Conventional explanations for accidents use notions such as operator error; faulty design or equipment; lack of attention to safety features; lack of operating experience; inadequately trained personnel; failure to use the most advanced technology; systems that are too big, underfinanced, or poorly run. ...[These] conventional explanations only speak of problems that are more or less inevitable, widespread, and common to all systems, and thus do not account for variations in the failure rate of different kinds of systems. [213]

Systems

Systems are conceptualized in a flexible scheme consisting of four different levels of components with increasing aggregation: part, unit, subsystem, system. The first level, a *part*, represents the smallest component of the system that is likely to be identified in analyzing an accident. It could be a valve, switch or indicator light that failed, thus preventing normal actuation of the landing gear, say, on an airplane. For analysis purposes, humans in most systems are treated as "parts" and a "human error" or "operator error," such as forgetting to lower the gear, is considered a part failure.

The second level, a *unit*, consists of functionally related parts such as those that make up the landing gear. The third level, a *subsystem*, is an array of units such as the landing gear, pumps and motors, hydraulic piping, controls and indicators, etc., that constitute the retractable landing gear subsystem. The fourth or highest level is the *system* under analysis, for example the airplane, which consists of several subsystems. Beyond this level is the environment of the system.

Note that this scheme is flexible in terms of what level specific components are classified into. It depends on your point of view for the analysis in question and thus is relative to the system under consideration. That is, if we were analyzing the air route traffic control system between Chicago and New York, airplanes enroute might be considered a "subsystem" with each airplane viewed as a "unit" in the system that may have a "part" failure such as a transponder, radio, or operator. Cut another way, one may be concerned with the communication subsystem, radar tracking subsystem, or radio-navigation subsystem and their associated units (e.g. VOR's, TACAN's, radio beacons, etc.) and their parts (transmitters, receivers, antennas, operators, etc.). From a very broad perspective, examination of the transportation infrastructure of the U.S., say, would imply that the air transportation "subsystem" contained some "parts" called airplanes. Or, going the other direction if we defined our system from a narrower perspective, the crew of an airplane would be considered a subsystem of the aircraft operation and control system.

Accidents

With these concepts in mind then, Perrow defines an accident relative to the system under consideration. An accident involves unintended damage to a defined system that disrupts the ongoing "tasks" or future tasks that will be demanded of the system to procure its output. What we might consider tasks depend on what we call the system. The degree of disturbance is also related to what we define as the system. The collapse of an aircraft landing gear as the pilot of the airplane inadvertently dropped one gear off the taxiway enroute to its parking place would surely be an accident for that airplane, its owner, and the airport manager. But it would have little effect on the air transportation system of the U.S. Also, not all disruptions should be classified as accidents; the damage must be reasonably substantial. An unsafe gear warning light may cause considerable disruption for the crew, the arrival airport, scheduling for the airline operator and so forth, but if a safe landing is completed we would not call such a disruption an accident, even though it was unintended and had unfortunate consequences (economic, inconveniences, etc.) for the system. Such "minor" event disruptions, Perrow calls incidents.

The criteria Perrow uses to distinguish between accidents and incidents, he admits, is somewhat arbitrary, but it allows a definition that incorporates the flexibility desired in the notion of system described above. The term accident is reserved for the more serious matters -- those disruptions that affect the third or fourth levels (subsystems or system). The term incident refers to disruptions at the first or second level (part or unit) -- a single unit at most, even if that disrupts the output of the system. In summary, then:

> An *accident* is a failure in a subsystem, or the system as a whole, that damages more than one unit and in doing so disrupts the ongoing or future output of the system. An *incident* involves damage that is limited to parts or a unit, whether the failure disrupts the system or not. By disrupt we mean the output ceases or decreases to the extent that prompt repairs will be required. [214]

Now we can get to the notion of "normal accidents." It is important to distinguish between two types of accidents on the basis of whether any interaction of two or more failures is anticipated, expected, or comprehensible to the persons who designed the system, and those who are adequately trained to operate it.

> *Component failure accidents* involve one or more component failures (part, unit, or subsystem) that are linked in an anticipated sequence. *System* [or *"normal"*] *accidents* involve the unanticipated interaction of multiple failures. [215]

Thus when an unsafe gear-warning-light occurs, the trained operators anticipate that the landing gear may not be positively locked down and may collapse when the plane lands, resulting in damage to plane and perhaps injuries, fire and even death. This would be referred to as a "component failure accident." Although the direct cause of the landing gear problem may not be immediately known, the subsequent series of failures are expected and understood. Designers and trained operators understand such sequences but may or may not be able to intervene in the series of failures through backup units (i.e. mechanically lowering the gear, alerting fire crews, foaming the runway, etc.). However, when an unsafe gear light distracts the crew to the point that no one notices that the autopilot unintentionally became disengaged, resulting in a slow unnoticeable (without observing instruments) descent and no one monitored the state of the airplane or if they did (the air traffic controller, for example) they did not insist on clarifying the intentions of the crew; and, if no recovery was made before the system was damaged (the plane crashed) we would refer to this as a "system accident." [216] The essential difference is the unanticipated interactions.

System accidents, as with all accidents, start with a component failure, most commonly the failure of a part, say a valve or an operator error [that serves as a triggering event]. It is not the *source* of the accident that distinguishes the two types, since both start with component failures; it is the presence or not of multiple failures that interact in unanticipated ways. [217]

Of course incidents are much more common than accidents -- in fact, part or unit failures are very frequent -- and, among accidents, component failure accidents are far more frequent that system accidents, which makes system accidents all that more difficult to analyze and deal with. One final category, Perrow mentions as an aside, is the rare component failure accident in which the initial failure is so drastic that it is not worth tracing out the subsequent sequence, if one exists, since it does little to contribute to the understanding of the accident. An example would be the wing coming off an airplane.

Complex Interactions

Interactions that are expected and/or readily apparent when they occur do not represent the kind of phenomena that results in Perrow's notion of system accidents. Perrow refers to these as "linear" interactions; production is carried out through a series or sequence of steps laid out in a line[53]. Most of our planned life is organized this way as are a large portion of the systems we encounter. Interactions occur in an expected sequence.

However, as the size of systems increases, and the number of diverse functions they serve increase, and as systems are required to function in ever more hostile environments with increasing ties to other systems, we can expect more and more incomprehensible or unexpected interactions. These are interactions which were not

53 An assembly line is an excellent example, although the notion of "linear system" should not be equated with the physical layout of a plant or production process. It does not necessarily imply an assembly line, even though these are linear.

intended in the design or they were intended but rarely activated (some backup systems, for example) and thus they get forgotten by designers and operators. This "complexity of interactions" makes the system more vulnerable to unavoidable system accidents.

An excellent example of complex interactions that are unexpected and incomprehensible is that portrayed in the recent NBC television drama "Crash: The Mystery of Flight 1501." The drama is a paradigm of a system accident. This is a story about a plane crash that initially was thought to have been caused by "pilot error." Two things pointed the NTSB to that conclusion. First, the pilot flew into a thundercell, choosing to follow indications on his own inflight radar as opposed to vectors suggested by the controller which would have put the airplane on a path to avoid the storm. Second, as the airplane became uncontrollable in the storm, it entered a rolling dive and crashed. The flight data recorder indicated that the pilot could have recovered from the unusual attitude; but he failed to use right rudder which would have allowed the aircraft to recover from its roll and avert the crash. The question was raised as to whether the pilot's judgment was affected by the use of a perscription fertility drug he was taking that was not approved by the FAA.

As it turned out, the accident involved aircraft equipment malfunctions that were due to a piece of equipment and container of material being transported in the cargo compartment, each shipped by different agents with contents unknown to the airline. Live electronic equipment (that was not shut down in order to save time) was responsible for shifting the image on the inflight radar by a 30° rotation, which produced information about the location of the storm that was incongruent with ATC's radar. The pilot chose to follow the onboard information. There was also some hazardous material shipped illegally that started a fire in the mid-cargo section that slowly burned through rudder controls undetected. Thus the pilot had no rudder response when he needed it. The fire also shorted wires that popped the circuit breaker on the voice recorder so that the investigators never heard the pilot's words "I've got no rudder." Also, the crash and subsequent fire had initially camouflaged the evidence for these two pieces of cargo.

Seem unfathomable? Read Perrow's accounts of some unfathomable aircraft system accidents which occurred due to minor electrical malfunctions in the galley. The blatant point is that we cannot possibly foresee all possible interactions of multiple component failures, or understand them when they occur. But they will continue to occur with greatest probability (however infrequent) and impact in systems that are complex and tightly coupled. Therein lies the paradigmatic irony of the last statement in the drama, an irony that unfortunately goes wanting for most viewers. A news reporter sums up the situation: "The only comfort we can take in this tragedy lies in its uniqueness; its very oddity assures us it can never happen again."

This "linear" versus "complex" characterization of systems does not represent a dichotomous partition of the set of all systems. We are concerned with the degree of linear (expected sequence) or complex (unintended or intended but unfamiliar) interactions. "Linear" systems have very few complex interactions; complex systems have more complex interactions than linear systems but complex interactions can still be fewer in number. Also, a complex system does not necessarily imply highly sophisticated technology, numerous components, or many stages of production; it could be a complex organization that serves many functions such as a university or government agency. In fact, it would be inappropriately restrictive to interpret this discussion of systems and their complexity as referring only to technical aspects of systems. The Air Route Traffic Control System, for example, is a complex socio-technical system that we may wish to view in its entirety, including its technology, operators and the organization that designs, manages and maintains the system.

Some common system characteristics that exacerbate the complexity of its interactions include such things as components which serve mutliple functions resulting in common-mode failures; proximity of system components (especially those with unrelated functions); multiple branching paths and other conditions allowing jumps from one linear sequence to another; feedback loops especially with long time lags; and various other ways that multiply connections as other parts, units or subsystems are reached. In good system design work we intuitively try to construct the system in a way in which interactions are planned and visible to the operator, focusing on the virtues of simplicity and comprehensibility. To keep systems as linear as possible we design in buffers, engineered safety devices (ESD's) and information management systems that can help defend against unexpected interactions by making the connection between events more visible. However, even linear systems have at least one source of complex interactions -- the environment. Since it impinges upon many parts or units in the system simultaneously it can be a source of failure that is common for many components resulting in a common-mode system accident. Severe icing would be an excellent aviation example.

System Coupling

System coupling refers to the amount of slack or buffer among the system components. "Tight coupling" of two components means there is no slack or buffer between them; an impact on or a change in one component directly affects what happens to the other. The coupling in an aircraft aileron control system, for example, is very tight. When the pilot turns the yoke handle, the ailerons respond immediately through electromechanical and hydraulic actuators, and the airplane responds accordingly. In fact, virtually all aircraft systems are necessarily tightly coupled with the exception of the crew which provides a buffer between subsystems. On modern aircraft, however, an entire flight can be flown from takeoff climb to destination landing with the aircraft navigation and control systems coupled to a computer which, in turn, automatically tunes in and locks on to succussive ground navigation aids (VOR, DME, ILS, etc.) along the route, thus coupling the aircraft to the ground air route navigation system.[54]

On the other extreme, a university is an example of a loosely coupled system. What goes on in a given classroom or lecture in all likelihood has no impact on, nor is it impacted by, what the administration is doing that day. Even when there are programs such as a university's new emphasis on Total Quality Management, there is a large gap between the initiation of such a program and actual changes in the behavior of teachers and the quality of education in the classroom. Even in a more tightly coupled system such as an aircraft manufacturing company, a goal may be set to reduce defects by a factor of 10, for example, with the intention of achieving it through a new total quality management program supported by a strong budget for prevention. But anyone who has worked in a manufacturing environment such as this can relate to the enormity of the gap between such a goal and the actual desired results. If the program is supported and managed properly the goal may eventually be achieved -- after a considerable period of time. Its effectiveness depends on how loosely or tightly connected the goal is to the other matters with which the organization is preoccuppied (production goals, union demands, etc.). Existing ways of doing things are buffered by the organizations inner structure and its motivation and reward

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54 Backup systems are part of the programming so that an invalid navigation aid can be detected, thus providing some buffering between the air and ground systems.

system. Unless these are changed to incorporate the new goal and the means of achieving it (training in TQC concepts, SQC, etc.) the system will be so loosely coupled that the anticipated results will not follow from the goal.

It is important to note that loose coupling does not mean disorganization; the degree of organization is independent of the degree of coupling. A university, for example, can be well organized with a large set of congruent interests, mechanisms for accomodating various arrangements, stable interaction patterns, and slack resources to meet unexpected challenges. The key notion with respect to coupling is the responsiveness of systems to failures or shocks. There is good and bad at each end of the spectrum.

> Loosely coupled systems, whether for good or ill, can incorporate shocks and failures and pressures for change without destabilization. Tightly coupled systems will respond more quickly to these perturbations, but the response may be disastrous. [218]

Summary of the Paradigm

In summary, Perrow's paradigm of normal accidents is characterized by two system phenomena. First, unanticipated and/or incomprehensible interactions of multiple component failures are system characteristics that are exacerbated by system complexity. Second, the seriousness of such failures in terms of their propagation rate (time to diagnose, correct, isolate or mitigate the initial failures), extent of impact, and resultant system destabilization and catastrophy are system characteristics that are exacerbated in tightly coupled systems.

The following two tables summarize system complexity and coupling as Perrow has developed these notions in relation to his paradigm of normal accidents. Note that a "component" can be any element of the system (Design, Equipment, Procedures, Operators, Supplies and materials, and Environment -- "DEPOSE"). Also note that the opposite of "complex," in Perrow's sense, is not "simple;" nor is the opposite of "linear" to mean "non-linear." [219]

Table 5.1 System Complexity Characteristics

System Interactions		
	Complex Interactions	**Linear Interactions**
Nature of the Interaction	One component can interact with one or more other components *outside* of the normal production sequence, either by design or not by design	One component interacts with one or more components that precede or follow it immediately in the sequence of production of system outputs
As Affecting the Operator	Unfamiliar sequences, or unplanned and unexpected sequences; either not visible or not immediately comprehensible	Expected and familiar production or maintenance sequence; quite visible even if unplanned

Table 5.2 System Coupling Characteristics.[220]

		Characteristic System Tendencies	
		Tightly Coupled	**Loosely Coupled**
Criteria	**Time**	Highly time dependent -- cannot wait or standby until attended to	Delays possible -- processes can remain in a standby mode
	Sequences	More invariant -- difficult to adjust sequences in case of disruption	More flexible -- adaptable
	Overall Process Design	Unifinality -- only one way to reach the production goal	Equifinality -- many ways to achieve the production goal.
	Slack	Very little -- precise quantities; no resource substitution; wasted supplies may overload the process; failed equipment entails shutdown (temporary substitution not possible)	Considerable slack -- supplies, equipment and human power can be wasted without great cost to the system; system not shut down by temporary interuption

Implications for Aviation Safety

Aircraft and the national air transportation system are complex and tightly coupled. Yet as noted in Chapter 1, commercial air transportation as a whole has become quite safe; most of us do not fear for our lives when we board a commercial airliner to travel somewhere. But system accidents do occur and when they do they are often catastrophic due to the number of lives lost, calling out for investigations and improvements for flight safety.

Perrow notes that the unique structural conditions of this industry promote safety, despite complexity and tight coupling; and technology has played a significant role as well. The FAA has also been pointed to as a "high reliability" organization, one we should study and learn from. [221] Perrow provides, however, several excellent examples of flying system failures that are paradigms of normal system accidents in which simple component failures resulted in catastrophies due to complex interactions in a tightly coupled system. He differentiates those "flying" (airplane and crew) failures from the hazards of navigating the airways (the aircraft, crew, other aircraft, and ground control) because, he states, the airways have been structured in such a way that has linearized their operation through proper partitioning and control of the National Airspace System. He acknowledges, though, such problems as airplanes not under radar control who fly where they shouldn't; and the impact of traffic intensity is clearly brought home with the eye-opening example of Orange County Airport in southern California.

Even though accidents, in general, have become quite infrequent in commercial aviation, the system characteristics will continue to exist for "normal accidents." As we have seen with MAC flight 40641, even under light, routine operating conditions, components of even the air traffic system can fail and interact in unanticipated, even unnoticable, ways until it is too late.[55] The potential for system accidents increases when the slack or buffer is systematically squeezed out of the system. And that is just what production pressures and bottom-line push for ever more cost efficiency have a tendency to do. Design improvements that enhance the margin for system safety are often subverted by the continual pressure to operate at the limits.

The other question that needs to be raised in the context of the normal accident paradigm is that of technology. Ever more complex and advanced technology is continually entering the flight domain. How will it affect system coupling? How will it affect the operators' abilities to anticipate interactions, comprehend them in their complexity, and react to them? Is it reasonable to assume that more and more advanced technological systems will not increase the potential for incomprehensible and unexpected system behavior when components fail, as components will with certainty? We will explore these notions and others in the next chapter, "The Paradigm of Technology."

55 We will explore these notions for the MAC accident later on.

Chapter 6

The Paradigm of Technology

In developing a paradigmatic view of technology and its implications for aviation safety, let me begin with the broader historical context by briefly sketching the course of technology relative to its promise; and then characterize the pattern of technology which paradigmatically explains its nature. This is the framework of Albert Borgmann [222]. Borgmann's philosophical inquiry into the nature of technology has been focused on modern technology as it characterizes contemporary life, and the profound way it articulates the world and structures our engagement with it in the inconspicuous everyday world of labor and leisure in an advanced industrial country such as ours.

Although Borgmann's concern has been with the pervasive influence of technology in our everyday life and its subsequent impact on focal things that used to orient and grace our lives as individuals and as a society, the paradeictic explanation of technology that he has illuminated has enormously broad and far reaching implications. The key point I wish to make here is that the pattern of technology affecting aviation is part of a broader paradigm that has radically transformed our modern world and thus should be considered as fundamental to the paradigmatic context of flight safety. I make no pretense of a developed justification of Borgmann's views, but merely describe the pattern he has developed and then consider, in a more focused sense, its implications to our paradigmatic explanation of flight safety. The foundation and richness of his philosophy cannot be fully appreciated without reading his works.

One aspect of technology that Borgmann has not chosen to deal with, however, must also be considered as it helps us flesh out more of the "how" technology proceeds in its paradigmatic background. It is that of the pervasive and persistent expectations that characterize the human enterprise or "technostructure"[56] itself. These expectations represent a certain background of normative values that are mutually shared

56 The highly trained research and development scientists and design engineers, manufacturing and process engineers and organizational experts in the other functional areas of business including marketing and finance, planning, scheduling, maintenance and so forth.

by all of the technological fields and are passed on and maintained through the education and socialization of the technological professions. These values are expected in industry to guide the behavior of those who participate in the background processes of technology. This perspective on technology comes from David Bella [223] and he refers to it as the "technological background" that has become an integral characteristic of our technological culture. The engineering profession provides *the exemplar* for this aspect of technology; and by "exemplar" I mean not just an example that is used as a model, but through the primary sense of the word, something that *should be* imitated, something that serves as an *ideal* example by reason of being worthy and truly representative. These shared expectations relate to the way in which technology successfully moves forth, but their force in our culture goes well beyond that of the technological disciplines. Through the steady, widespread and cumulative influence on our technological world, these expectations have become an integral part of our everyday framework via "subtle accomodations of relationships, language, and perceptions as people learn to get along in this technological world" [224]. Bella's perspective on technology is not at odds with Borgmann's; in fact, it complements it within the same framework as we will see below.

The Course of Technology

Let me emphasize at the beginning of this discussion that, throughout this work, I am attempting to broaden our perspective and expand the cognitive framework through which we view and understand aviation safety; the path to achieving this is an examination of its context. In order to do this, we must continue to practice standing back from the immediate and specific environment of aviation and elucidate the relevant contextual patterns in their broadest sense. Such an approach is most apparent in the pattern of technology as we attempt to understand its meaning and implications for us. The brief discussion that follows provides an even broader context for understanding the pattern of technology and the way it has influenced human life. It gives some historical basis for comparison of modern technology; thus the ideas are best introduced with examples from everyday life. As with most contextual developments, the relevance to aviation safety will not be immediately apparent. Bear with the discussion, if you will, and its contextual relevance will begin to take form.

From a very broad historical perspective, the course of technology has manifested itself in three distinct phases which Borgmann refers to as: pretechnology; the promise of early technology; and, the irony of mature technology [225]. Pretechnological societies were characterized by a certain "hardness of life" that had both positive and negative aspects. On the negative side, life involved toil, confinement, passivity and suffering. In daily life and through the imminence of crises, people routinely faced duress, hunger, cold, hard work, oppression, famine, pestilence, war, disease, injury and harm. They were confined to the village most of the time as travel was arduous; and, to the social class into which they were born. But this hardness of life also provided a firmness in a sustaining and consoling sense. There was firmness in physical settings and it provided contours to the social structure of the community. The duress required fortitude and the firmness imposed fidelity; both went hand-in-hand as one was truly engaged with the world in his daily life. And there was much joy in this life.

In the early constructive phase of technology, life appeared in a new light. Technology promised liberation, enrichment and conquest. It provided liberation from disease, ignorance and illiteracy. It enriched people beyond necessities and provided for mass consumption. Technology, through its transformative potential allowed for the conquest of nature, space, time, and behavior on the basis of science. Liberation, enrichment and conquest were the essence of the promise of technology, freeing human beings from toil, confinement and suffering. But as society entered this phase, two things occurred. At first, there was ambivalence toward the hardness of life. On the one hand it provided a firmness to life, but people were undecided whether the duress was worth the firmness it instilled in them. Eventually, though, the promise of technology and its fruits left a legacy in which the tolerance for duress became low. In fact, in modern day we find it unimaginable that there can be joy among duress; but there was joy in the midst of pretechnological duress. In fact, duress was borne lightly.

But as technology matured into what we now call modern technology, the promise of technology ironically has been subverted in many ways. In this phase, the fabric of life itself has lost its firmness and has become ever more shallow, played out essentially in the consumption of commodities. The liberation from toil that early technology provided has become disburdenment from hassles which, in turn, breeds disengagement from significant and orienting aspects of the world. The TV-dinner, for example, eliminates the hassel of having to plan, coordinate family schedules, prepare and clean up after a meal. Everyone can just grab one from the freezer and, after a few minutes of heating, one can eat a warm meal, unconstrained by anyone else's schedule or other hassles. It serves the function of filling our bellies rapidly but as a consequence we are disengaged from the central activity the family meal used to be.

Enrichment by way of diversion is overtaken by distraction as in the television "couch potato" syndrome. There is no effort, no engagement, no skill, no self discipline. And finally, conquest makes way first to domination where the drive is to overcome something once and for all, and then to loneliness where we see more isolation of individuals and work groups accompanied by frustration and lower morale. We are intent on "solving the problem" to get it out of our lives. We have developed techniques for "handling people," for example, or solving the human reliability problem permanently by replacement with machine. We lose contact and spontaneity as more and more of our communication becomes replaced by "techniques of management" and information exchange through computer networks and electronic media. It is literally becoming difficult to speak directly with a human over the telephone when you call some business. You get a recording that says "dial 1 for this, 2 for that," and so forth, until finally you end up having to leave a message on their "voice mail." Such developments allow us to communicate with more people, but on a shallower basis.

> Few will argue that technology has helped make the modern office more efficient. Memos can be quickly disseminated electronically to entire staffs via computer. ...Just leave an excuse [for missing a meeting] on voice mail. ...But some organizational experts are questioning what all these advances are really doing for communication.
>
> "It can be abused quite easily to avoid situations and in-person meetings," said a human-resources consultant. "I know people who have been reprimanded through their voice mail. ...It's really easy to get in the habit of leaving a message instead of taking a few minutes to walk down the hall and talk to someone in person. It's very efficient, but it has an adverse effect on communication and people getting along together." [226]

Increasingly the concern is expressed -- even where there is strong desire and effort for spontaneous, interpersonal contact as it is in independent investigative journalism. Prestigious assignments such as the White House beat, it is reported, are a paradox of high profile empty experiences because "there is so little opportunity to get something that everyone else doesn't get. ...The number of reporters covering the president keeps growing while the control a president exercises over the flow of information gets tighter." [227] And some see the impact in international diplomatic relations as well. [228]

The recent film *Avalon* (1990) is a poignant dramatization of the paradigm of technology. The depth of this drama is not carried in the lines of the actors, but in the subtle way its development illustrates contextually the historical intrusion of television (among other things) into our lives, accompanied not only by diversion and distraction, but by disengagement from the centering experiences and activities of (ethnic, in this case) family gatherings and celebrative meals. And ultimately, disintegration of the extended family is accompanied by distraction, loneliness and despair.

Borgmann also describes a fourth phase in the course of technology in which the firmness of life and the promise of technology can be regained from the decadent aspects of modern technology. He calls this reform phase "metatechnology." [229]

The Pattern of Technology

Borgmann has acknowledged the difficulty in developing a precise and penetrating inquiry into the fabric of technology, as it characterizes our time in an advanced industrial society. [230] There is an elusive character to the problem, which is peculiar because of the sense of normalcy about technology. It is all around us and seemingly abounds with familiarity. Its disciplines, processes, products and procedures are highly articulated, explicit and certainly do not suffer from a lack of attention. Yet technology has become a part of our life in the most inconspicuous and inescapable fashion. Thus, Borgmann develops his penetrating analysis not in the context of extraordinary technological achievements or threats to technology, but in the ordinary world to which we are all committed. And pursuit of this problem has required a broadening of method, that of paradeictic (or paradigmatic) explanation [231], which we have discussed at length in Chapter 2.

Functionalism and Devices

The pattern of technology, as *the* paradigm which explains the nature of the contemporary world, is manifested in the nature of functionalism and technological devices [232]. Borgmann illustrates this through the example of the home heating plant.

> The technological device is the radical and increasingly sharp separation of means from ends. A heating plant has the sole purpose of providing heat. This is its function, and it remains relatively stable. The machinery of a device is indefinitely variable within the boundaries of the function. A totally new and different machine will constitute a better but not a different device. Thus it makes no difference whether the heat comes from coal, gas, or oil, whether it is pumped, blown, or radiated. Given that variability there cannot be such a thing as the essence of the machine which would characterize technology. ...But there is something like the essence of the device. [233]

The significance of this trend in means-end separation is highlighted by contrasting modern-day heating with the pretechnological era.

> In the pretechnological world, a means is always more than merely a means. In the wood which burns in the stove there is the work of felling, sawing, and splitting, there is the age of the trees and the species which the land and the climate favor. The stove will bespeak an origin and a history of ownership. Correspondingly, there is no mere end. The burning of the wood indicates the weather when the draft is poor or the stovepipe is red in response to the cold. The stove constitutes a focus, i.e., hearth, of warmth and comfort and thus concentrates the house. A heating plant provides warmth and nothing else. [234]

Since the machinery of a device is highly variable, even unpredictable in terms of the inventions upon which it rests, what is it that characterizes what we call "technological progress?" It is seen in the nature of the function itself and the need that it serves through the commodity procured by the function of the device. Borgmann notes that although the function of a device remains relatively stable in comparison to the machinery, "in the progress of technology, the function increases in prominence and purity whereas the machinery shrinks and recedes." [235] The function becomes emancipated from the machinery of the device.

The home television set exhibits this in an especially striking fashion. Its function has been to present a transmitted video image vertically. Although it has been refined over the past 50 years with color and purity, the function itself has changed very little. But the machinery has changed radically and receded to the point that no more than a button push from one's own chair is required to operate the device. No longer must we play with tuning and adjustment knobs, which have themselves receded into automated tuning. No longer must we wait a considerable period for the tubes to warm up. In fact, we have no tubes to be concerned with. Undoubtedly, anyone with gray hair knows what the inside of an old TV looked like because we had to get in there quite often to pull its tubes and test them at the local grocery store and replace the bad ones. Old sets required that sort of involvement. Now, virtually no one has any idea of what a modern TV even looks like inside. We have seen the device become more and more compact, taking on transistors, and then digital circuits. There is no doubt that the machinery of this device will regress to the point that it eventually will appear as a thin flat surface, that can be hung on the wall of one's "media room."

We could go through such an examination of virtually any device. Think about what has happened to the audio tape recorder. And the home is destined to become one big intelligent device. We encounter glowing reviews of such technological progress in the routine flow of daily information. The barrage of publicity and advertising encourages us to view such developments with awe, marvel, and reverence for the wonders of modern technology. This is the cognitive framework of our everday life. We define our wants and needs through the images presented to us. Recently we have been told, for example, how the house itself is becoming a hassle. The multitude of convenient household devices we need in order to get by in this modern world are troublesome to understand, control and coordinate. What we need now is a central command and control center to function as a "brain" for the "smart house," relieving us of the burden of having to manage all of the individual "smart" devices.

> Despite [a variety of smart devices in the home], the house itself remains essentially dumb, a passive shelter for a tangle of separate systems and appliances. ...The goal of the smart house project is to set the stage for a whole new generation of programmable household systems only now being invented. ...The possibilities become more exotic. Calling by car telephone, for example, a person stranded in traffic could turn off the coffee maker or tell the microwave to begin defrosting dinner. Videocassette recorders could be signaled to tape the nightly news. [236]

> If you never figured out how to program your setback thermostat, don't despair; your next house may do it for you! ...For $50 you can buy enough components for a system that lets you control up to 16 lights and appliances from your easy chair. ...The ultimate high-tech home contol system will enable you to program your entire house. This means... [237]

The Function-Needs Singularity

But one must consider what happens to the human needs that the function serves in order to fully appreciate the impact of the the device.

> At first the needs seem as firm as the functions. But closer inspection shows that as a function increases in purity, it isolates and transforms a need more and more radically. There is a mere and unmediated need for warmth only once there is a device which singles out and satisfies that need without addressing any other sensitivity or interest. The end of

the device is the full and exclusive termination of function and need without disturbance or presentation of further relations. In their isolation, all needs appear as equally important, and hence their number can be increased indefinitely. [238]

In the pretechnological era, needs were deeply and uniquely rooted in their context. This gave them a basic firmness through their manifold connections with the world. In the modern era, the substance of things that used to make up our world are increasingly disolved or replaced by *functions*. When needs become functionally isolated, their nature changes in a profound way. Once uprooted and severed from their context, their basic status disolves and they can be multiplied and modified at will. [239]

The radical isolation of needs and the emancipation of functions are mutually reinforcing. The isolation of needs requires the autonomy of technological functions; and the freeing of functions from the machinery of the device leads to the isolation of needs. Consequently, function and need combine in a sort of singularity; that is, they meet in a narrow and sharply delimited area. Borgmann calls this a "punctual conflation" (combining at a point) where there is no overt transformation or disturbance of the context. [240]

A function, once it has isolated a need, tends to accommodate itself entirely to the satisfaction of the need and requires no apparent thing for identity and presence; the switch disappears in a homeostat or timer, the device is reduced in its presence to its effect. As the function emancipates itself from overt things to the point of disappearance so the corresponding need is isolated to the point where it is entirely free of interconnections and communications and is silenced to a state of inconspicuous normalcy. Heating, from this point of view, is usually quite advanced whereas lighting and the providing of food are less so. The tendency, though uneven and various, is quite general and can be seen in the development of cars, houses, entertainment, and other things. [241]

Even the distinction between elementary needs (i.e. food and warmth) and adventitious needs disappears because an emancipated function transforms a need when it isolates it.[57] The elementary needs get deprived of their basic status as they are...

...assimilated into the indefinite number of needs that are isolated if not created by novel functions with little or no foundation on the elementary level. Being supplied with television and deodorants is no longer considered to be very different from being supplied with warmth. [242]

What brought about the TV remote control device? The even more isolated need of changing channels without the hassle of getting up out of our chair; and, concurrently, the emancipated function of remote control. In the future the machinery

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57 Unless the elementary needs remain unfulfilled, thus threatening human existence, or their satisfaction requires sustained and wide-ranging effort as in self-sufficient farming, for example.

(hand held control) will recede even further as we will be able to just tell the TV, "On; Channel 4," which will eliminate the hassle of having to remember where you last left the damn control. And, of course, such progress would not forget the infamous VCR, with all its complexity of operation.

> Beck [a chief scientist at a California computer firm] imagines a VCR that could be programmed by voice -- as many as six different voices for family members. ...You say, 'Get me Nova, 9 p.m., Tuesday, Channel 9, one hour,' and it does. [243]

Consider the automobile as more and more sophisticated devices emancipate functions that transform, isolate, and proliferate needs for the basic operation and control of the vehicle. We no longer need be hasseled with such burdens as looking down at the dashboard, or the ability to read a map, as technological devices address the functions of monitoring and navigation.

> General Motors' head-up display (HUD) uses technology borrowed from jet fighters. ...[This device] projects a hologram-like display of the speed, turn signals and fuel indicator onto the windshield ...[which] eliminates the driver's need to take his or her eyes away from whizzing traffic. ...GM's color touch-screen Visual Information Center (VIC) ...incorporates [a device] that you touch to control automotive systems, such as the stereo system (including its equalizer) and climate control. What's more, VIC's electronic dipstick signals you when it's time to add or change oil, ...Its electronic compass is the shell for ...the Travel Pilot, [which] is a James Bondian navigational system with Silicon Valley roots that gives drivers a new sense of direction by providing on-screen display of the car's location, destination (pinpointed right down to a street address) and the best way to get there. On-board sensors and a gyro-compass guidance system connect with a compact disc data base of maps. ...The system tracks the vehicle's progress, updating the location every second or so. ...[And among all these other functions, VIC can even] alert you to meetings, special dates and other events.
>
> Chrysler Corp's Visorphone ...features one-touch dialing and hands-free talking, ...with a special microphone fitted into the visor and a speaker in the car's dashboard. [The required one-touch dialing can even be eliminated by meeting the dialing need with] Uniden's Audiobox, a no-hands dialer with a voice-activated feature that accepts recited numbers. ...[And security can be easily procured since] cellular telephones are being coupled with new anti-theft services available through cellular networks. ...The phones will call you, a monitoring station or the police to signal that someone is tampering with your car. [244]

Technological Progress: Availability and Procurement

With this mutually reinforcing tendency toward an indefinite proliferation and refinement of function-need singularities, the state of progress or perfection is measured by the criterion of instant and universal *availability.*

To continue with examples of technological progress in the automobile, consider the isolation of the need to eat and its functional procurement through devices which make the commodity ever more available.

> ...she just cannot spare the minutes for stationary meals. With time pressure and long commutes to work, dashboard dining is fast becoming the norm across the nation. The trend is becoming so pronounced that it is affecting the design of cars and the packaging of food.
>
> "One-handed food," said a professor of food marketing. "The food industry will continue to offer packaging and food products that are easy to open, quick to heat and quick to eat. Hands will replace knives and forks as the utensils of choice." ...By 2001, a quarter of all breakfasts will be eaten in vehicles and a quarter of all vehicles will be equipped with microwave ovens. [245]

If we view *procurement* as "the enterprise of rendering things available" [246], the notion of device takes on a wide-ranging and recursive nature. Borgmann draws the connection this way:

> The complete fulfillment of a need without further distractions or demands requires that the function of the device is ubiquitous and comes into play instantaneously; it must be easily manipulated and safe. These four traits of a function's presence can collectively be called availability. We can say conversly that whatever is truly available is a device. This suggests that things other than instruments or implements can be procured as devices. The machine device exhibits the technological paradigm most apparently. But social institutions and works of art can also be procured as devices. Technology is more than a matter of machines. [247]

The insurance industry, for example, is a technological device that procures security through a financial commodity, namely a guarantee of a cash payment. The machinery of this device is not primarily physical, but a network of computations, contracts and services. These are concealed and inaccessible to the ordinary person and the device exhibits the disburdening character of technology. The final consumption good is commodiously available security of a certain type through a call to the insurance agent.

Thus we can view large complex sociotechnical systems as devices. The national air transportation system is a device that procures rapid, safe and commodiously available transportation. In fact, even politics, Borgmann notes has become the "metadevice of the technological society." Where ever subsystems of societal technology conflict or founder, there is a call for political action to "procure ease and safety for the system as a whole." A government agency can be seen as a device for the procurement of a definite social benefit. [248]

The pattern of technology can be explicated at different levels and drawn from different sides, but it has a sort of functionally recursive or nested nature to it through which this same pattern of the device can be seen in the background machinery. The air transportation system is a device that procures an ultimate commodity, rapid transportation, for end consumption. But the machinery of this device contains devices itself that are paradigmatically similar. The airplane which does the actual physical movement is a device which contains yet other devices which procure, for example, navigational information.

The prolific pattern of functional emancipation and isolation of needs is pervasive and relentless. And the machinery is ever more concealed in the background and increases in complexity, and it becomes ever more sophisticated and inaccessible to the consumer of the commodity. But the commodity that the device procures is made ever more available with ease and simplicity. On this point, however, one could argue that technology has failed the pattern in this respect; that getting at the commodity "with ease and simplicity" is not without its own difficulty as the machinery of devices becomes more complex, sophisticated and inaccessible to the average person. The *Newsweek* article cited above illustrates the public recognition of the increasing difficulty of "interfacing" humans with ever more complex technology. Yet this situation is just another manifestation of needs created and transformed by the function that the machinery itself serves, and it gets defined as a human factors design problem.

> Design experts increasingly believe that the fault lies not with the humble consumer, but in the products themselves. ...The gap between the people designing technology and those who buy it just keeps getting bigger and bigger. ...The problem is the clash of cultures between engineers and consumers. ...[And] the syndrome of unworkable technology is far broader: from televisions to jet fighters and nuclear power plants. ...In the process of getting smarter, products have grown inexorably more complex, and more difficult to operate. [249]

Again, such a problem is just paradigmatic of technology itself. Functionalism is inherently instable. Needs are isolated and increase indefinitely; functions that address these needs are identified and emancipated from the machinery itself, freeing ever more of the machinery to recede into a concealed and inaccessible background. Intelligent machines now need even more intelligent operator interfaces, and it is the autonomy of such "intelligent functions," for example, that leads to the isolation of more and more needs. The machinery itself will be ever more variable in the background, constrained only by the transformative possibilities procured by science.[58] The foreground commodity becomes ubiquitous and instantly available with

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58 We are told in a current advertisement, for example, that "Lexus is now using a satellite to pinpoint Tim Murphy's last oil change." A stable function, scheduling an oil change, that has met a need long ago created by the machinery, the auto, itself isolates its own need. And we can see that the machinery which can serve that function is infinitely variable, from a note stuck on the door frame, to a "visual information center" in the car, to a satellite and the associated support machinery. One thing is for certain, Tim no longer must deal with the hassel of remembering when to change the oil.

ease and simplicity. Terms and phrases we now commonly use, such as "user friendly" and, in more technical circles, "intelligent operator-system interfaces" become part of our paradigmatic rhetoric.

> One solution to the gadget crisis may be what is dubbed invisible technology -- making computers, for example, that hide under the desk, with nothing but a simple screen atop the table. Instead of an intimidating keyboard, users might write directly on the screen with a special pen. ...The next generation of computer chips, already becoming available, may also help. These chips could be used to make the most user-friendly computers, appliances and cars ever. [250]

In summary then, one can abstract the pattern of technology paradeictically that is embodied in such clear examples. Central heating plants, airplanes, and T.V. dinners are technological devices that have the function of procuring or making available a commodity such as warmth, rapid transportation, or food.

> A commodity is available when it is at our disposal without burdening us in any way, i.e., when it is commodiously present, instantaneously, ubiquitously, safely, and easily. Availability in this sense requires that the machinery of a device be unobtrusive, i.e., concealed, dependable, and foolproof. The ensemble of commodities constitutes the foreground of technology in which we move by the way of consumption. The machinery of devices constitutes the background of technology. We take it up in labor by constructing and maintaining the devices of technology. This is the original procurement of devices and thereby of commodities. Derivative procurement takes place when devices are activated in consumption. [251]

Technological Background and the Human Procurement Enterprise

So if technology is the functional procurement of devices, and availability becomes a prevalent standard; procurement becomes a major force to make all things equally and easily present. There are certain goals or values integral to the paradigmatic machinery of technology that serve to keep the procurement running smoothly. They help guide our participation in the machinery and characterize the human enterprise of technology. These values are learned through experience as we participate in the social networks of the technological machinery and they become the sacrosanct expectations that define individual success or failure within the technological paradigm.[59] David Bella has elucidated these values as an integrated set of expectations [252].

* One should solve problems and complete tasks so that resources can be productively and efficiently put to useful purpose.

* Tasks should be broken down into workable parts that can be explained, completed, and evaluated in a practical and orderly manner.

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59 Many of them show up explicitly in performance evaluations.

* Information should be precise and unambiguous.
* Activities should be planned, organized, and controlled so as to meet specified objectives and minimize unanticipated changes, surprises, and disorders.
* Communicated evidence should be independent of personal feelings, emotions, needs, and experiences; it should be objective, factual, and nonsubjective.
* Evaluations, verifications, and validations should be based upon observations of performance.
* Time is a resource that should be used efficiently and not wasted.

Thus, this normative set of "shoulds" can be characterized by such key words as efficiency, productivity, utility, order, organization, control, objectivity, precision, performance, reliability, division of work and workable parts. As the essential technological background, they reflect the normal, common and expected practices of technological activity. They are the "deep givens" that are never really contemplated by those who share them. For example, when the author of a text on managing technology defines technology, at first broadly, as "knowledge of how to do things," and then more specifically for an individual enterprise, as "the capability that enterprise needs in order to provide its customers with the goods and services it proposes to offer, both now and in the future," he is referring explicitly to the manipulation or transformation of the physical world and information: "the universe I focus on is the physical world and the realm of information processing." [253] The technological background, though implicit in all that is discussed, is so fundamentally characteristic of technology that it escapes immediate observation, explication, discussion or critique.

The expectations become part of the framework of technology primarily through the influence of those whose work defines and sustains the leading edge of technology -- the engineering profession. But they are nonetheless imbibed by those who work and labor in the wake of technology as well. Bella states that "the technological background is essential to everything that we define as 'technological'." [254] He describes this side of technology as:

> A human enterprise within which a particular background of expectations exerts a pervasive and persistent influence upon human behavior. [255]

It has important ramifications that we will explore below.

Automation and People

Thus the paradigmatic machinery is driven by the continual refinement of needs and demand for ever more availability of commodities; functionally sustained by this background of expectations. And it finds its ultimate expression in the drive toward automation. As Borgmann writes:

> Work at the leading edge of technology is devoted to expanding and securing the device pattern in order to provide more numerous, more refined, and new kinds of commodities for consumption. Commodities are more fully available if the supporting machinery is less obtrusive, i.e., more concealed and reliable. Commodities are more numerous if the machinery is more productive. The ground level of the technological machinery is industry which produces goods and services. This basic machinery too shows a tendency toward shrinkage and concealment. But the emphasis from the start has been on reliability and productivity. Both ends are served by the division of labor. [256]

The work of dividing the labor, itself, was originally performed by the entrepreneurs and inventors of the early industrial age but has since been taken over and perfected by the technostructure, the highly trained people of the technological human enterprise. The goals of the division of labor, namely, performance reliability, efficiency and productivity, are primarily embodied in machines, not in their operators, and they primarily derive from their designers, not their users. The division of labor fits labor to the machine. Throughout the progression of modern technology, the force toward automation has been embodied in the values of the technological background.

> Machines were not only more productive than humans but also more reliable since they liberated production from the uncertainties and burdens of training and tradition, from the risks of individual judgments, and from the varying moods of the workers. The total liberation from these human liabilities is accomplished through automation. The latter was the implicit and sometimes explicit goal of technological production from the first. The goal is only now coming into reach... [257]

Computer networks, for example, are an integral part of the basic machinery of the airlines. They are the machinery of the flight reservation device and permit rapid and efficient scheduling and confirmation of customer flight requests. But they also provide for another function which is related to the efficiency of the human labor that is still required to process the requests and enter them into the system. Since all of the work centers around electronic devices, the machinery permits unobtrusive, even covert, monitoring and measurement of the work rate. It is not inconsistent with the background expectations of technology to incorporate this function into "management technique" to pressure labor to produce more and more work per unit time. Paradigmatically, there is no difference between this state of affairs and the auto assembly line and time-motion studies of the Henry Ford and Frederick Taylor[60] days. Work was measured, tasks divided and the speed of the line increased to get more work per unit time. Human labor becomes machinery in a paradigmatic sense. A recent New York Times News Service article poignantly illustrate how modern technology still effects this functionary pattern. Some excerpts:

> Now and then, Harriette stands up, defying the stream of calls pouring into her telephone. When she does, she said, her supervisors at the Trans World Airlines reservations office in Chicago call across the rows of sales agents and tell her to sit down. Although standing up slows production, it gives her relief from two-hour stretches of sitting at a computer terminal, and, she says, "It's a way to show I'm a person." But it is not just the supervisors who are watching her. Through her telephone and video display terminal, her employers constantly monitor her speed and efficiency.
>
> Harriette, 55, a veteran TWA agent is among millions of workers, women mostly, in the back offices of airlines, government agencies, insurance companies, mail-order houses and telephone companies who are the cogs in what some employees call an electronic sweatshop. Through the telephones and computer terminals they use, the workers and their performance can be watched, measured and analyzed in microchip detail. Some companies use the system openly and rather benignly to track their business and help laggards among the workers improve. ...But advocates for workers, like the organization Nine-to-Five, say other companies run dehumanizing pressure cookers, relegating management prerogatives to electronic taskmasters. They say the companies program high-performance goals into computers and push employees to work faster to meet them, much as manufactures speed up assembly lines.
>
> Because computers can measure quantity better than quality, critics of the monitoring systems say employees who do the fastest work often reap greater rewards than do those who do the best work. They complain of invasions of privacy, of managers who are oblivious to human needs and of stress-induced illnesses or injuries. ...Three years ago the Congressional Office of Technology Assessment estimated that 6 million to 10 million workers were regularly monitored electronically at their computers. Michael J. Smith [Chairman of the Industrial Engineering Department at the University of Wisconsin] said the number probably has doubled since then. At hundreds of companies, the performance of data-entry clerks is judged by the speed of their computer-measured keystrokes. Directory-assistance operators at telephone companies are allotted 25 seconds or less to root out a number, however vague the request, and computers record their times. [258]

Managements' perspectives are of course, different. Although TWA, whose agents are more vocal than others about the problem, declined to let a reporter interview management or to visit the office, a public affairs executive claimed they were no different than any other type of work place.

> From the standpoint of productivity, we believe it's possible for all agents to maintain the bench marks. We want to make sure the customers, paying hard-earned dollars, are getting what they paid for. [259]

60 Considered the father of scientific management.

Such comments not only reflect technological background expectations but the paradigmatic perception of availability -- the service must strive to be instantaneous. It is clear that the human in the system continues to create problems with respect to efficiency. At this point, it is dealt with through management technology.

> Agents in Chicago and at TWA's other telephone reservation offices in Manhattan, St. Louis and Los Angeles get weekly and monthly report cards based on the computer's measurements of the time they spend on the phone and on the supervisors' assessments of their phone conversations. Grades run from 1 (very bad) to 5 (very good). Workers earning 5s are awarded certificates that entitle them to an hour off with pay. Ones and 2s bring days off without pay and the possibility of eventual dismissal. [260]

Perhaps it is clear that such solutions are self defeating, leading to mediocrity and the need to eventually remove the human from the process.

> Some employees say they fight the system by doing less work. "I'm a 3," said a longtime agent in her late 30s who said she feared letting her name be used. "I could do better. I've been a 5. But I don't care. You don't get fired for a 3. I'm just biding my time." [261]

Even with the trivialization of work that such devices have brought on, management need not completely dehumanize it in the paradigmatic name of efficiency and productivity. One employee at Northwest Airlines Seattle reservation office commented about the new owner of the airline: "He said employees are paramount. He told us, 'If we can't make you happy, you can't make the customer happy.' ...He started treating people like family, not like slaves rowing across the ocean." [262]

But do we not see on the horizon, automation of this type of service. The response voice for a telephone number is already computer generated; will not technology solve the voice recognition problem for the request? Or, perhaps we'll be able to type in the request on our "compu-phone."

Borgmann has recently examined the microelectronics revolution [263] and questions how revolutionary the developments really are. His crucial perspective is the tie between the paradigmatic technological order and the developments in microelectronics. The distinction between machinery and commodity (information, in much of this case) becomes ever sharper.

> Devices that incorporate microelectronics, programmable or not, constitute the most advanced forms of such devices, both on the commodity and the machinery side. Such devices procure hitherto unavailable commodities, and they provide traditional ones in more refined, effortless, secure, and ubiquitous ways. These commodities rest on machineries which are more discrete and intricate and so less accessible and intelligible than preceding ones. But strictly within the device pattern, microelectronics is not revolutionary at all. It is merely the most advanced stage of a generally familiar and well-established development. ...While the machinery typically undergoes revolutionary changes which remove it ever more from the comprehension of the common person, the commodity generally develops continuously and makes ever slighter demands on the user's competence or care. [264]

A memory jumps to my mind which reflects this irony. Upon entering a Boeing 757 airplane for a trip one day, I managed some "flying talk," as I often do, with the young 757 co-pilot, a former Air Force C-141 pilot, as we were waiting. I asked what he thought of the capability of this "glass cockpit" to automatically plot its route, select, tune in and test, and switch to the correct navigational aids, automatically updating the flight computer as the plane progressed on its course -- all without any need for intervention by the crew. "You know," he said with honest reflection, "I feel like its cheating. You don't really even need to know much about flying anymore -- except for emergencies." Indeed, it brings into question what flying really is, what it is becoming, and what knowledge, skills, ability and engagement it should entail. On another flight, the response I got from the Captain of the 767 to my tongue-in-cheek question about forgetting how to fly, was: "No, I'm not worried about forgetting how to fly. In fact, the *computer* made that landing." Has flying become an exercise in menu selection and keyboard data entry? These reactions are typical of the empirical results obtained by Earl Wiener in his important study of pilot reactions to the "glass cockpit." [265]

Without proper reflection and some practice, it is difficult to recognize how pervasive and progressive the pattern of the technological device has become. And it is because the changes are so subtle. One does not notice the wall has yellowed over time until he removes the painting. More and more commodities, including unlimited forms of information, are ever more available, pleasantly and effortlessly at our disposal.

> These endeavors have the support and unchallenged, if uneasy, support of society. But all these commodiously available goods are procured by more and more complex and discrete machineries which, just because of their complexity and discreteness, are ever more removed from our competence. As we are moving more deeply into a Cockaigne[61] of consumption, we allow ourselves to be more and more disfranchised from competent and insightful citizenship in the technological society. ...On the labor side, ...liberation is promised from work that is hazardous, dirty, or monotonous. ...Labor, to be sure, has been rendered relatively safe, more pleasant in its surroundings, and much more lucrative. But typically it has been degraded all the same, stripped of initiative, responsibility, and skill. ...Through the microelectronic revolution the degradation of work comes to its conclusion in the elimination of work. The eliminating of hazardous, dirty, or monotonous work is merely an aspect of the larger phenomenon which will lead to the loss of more and more skilled work. [266]

61 An imaginary land of easy and luxurious living.

Indeed, even with respect to aviation, crew sizes have steadily dropped. The radio operator is now part of aviation history.[62] Navigation was automated[63] and then the functions of the flight engineer. And even still, there is talk of less than a two person crew for the future! Respected aviation human factors researcher Earl Wiener writes:

> Just at a time when the airline industry and unions are adusting to two-pilot crews on wide-body aircraft, there is discussion of the single-pilot crew, aided by intelligent computer systems. [267]

And elsewhere, though apparently for socio-political reasons they are not promoting it, Wiener and Curry certainly acknowledge the possibility of the unmanned airline cockpit.

> One hears, from time to time, talk of the unmanned airline cockpit. While the authors find this neither unthinkable nor technologically infeasible, we feel that, as far into the future as we can see, it would be socially and politically unacceptable. Therefore, while we do not completely dismiss the idea of an unmanned airliner, this discussion is based on the assumption that airliners will carry a human crew. [268]

At a minimum we are faced with a sobering concern: As a larger part of our world tends toward automation, disengagement and diversion will lead more and more to distraction, the scattering of our attention and the atrophy of our capabilities.

Summary of the Paradigm

The paradigm of technology is illustrated in the diagram below, Figure 6.1. [269] In the irony of mature technology, we see the promise of technology -- liberation, enrichment and conquest over suffering -- give way to disburdenment, diversion and domination. These phenomena come about through the procurement of commodities which are made available -- instantaneous, ubiquitous, safe, easy. Ubiquity means not only omnipresent in an everywhere sense but in such things as accuracy, maneuverability, speed, power, performance and cost. All of these are aspects of availability. Commodities are made available through technological devices. The

62 Except for specialty jobs that revolve around radio operators such as AWACS airborne radar control missions and electronic warfare missions, for example.

63 My old job (late 1960's, early 70's) on C-141's, for example, involved such skills as dead reconing; understanding of the jet-stream, wind and weather patterns; spherical geometry and Coriolis effect; star identification, the operation of a sextant and celestial triangulation. This job no longer exists as that navigational function-need singularity has been refined and picked up by radically different machinery that has receded into the electronics of the aircraft. The commodity (positional information) is now much more accurate and so simply available that *even pilots* can get it by themselves! Of course on airliners that are run by a computer, the pilots themselves don't really need it anymore.

foreground of technology is ultimately enacted in comsumption. Commodities are commodious -- comfortable, easily accessible, easy to use, and enjoyable without burdens and commitments. They link autonomous functions with needs that have become isolated from their context.

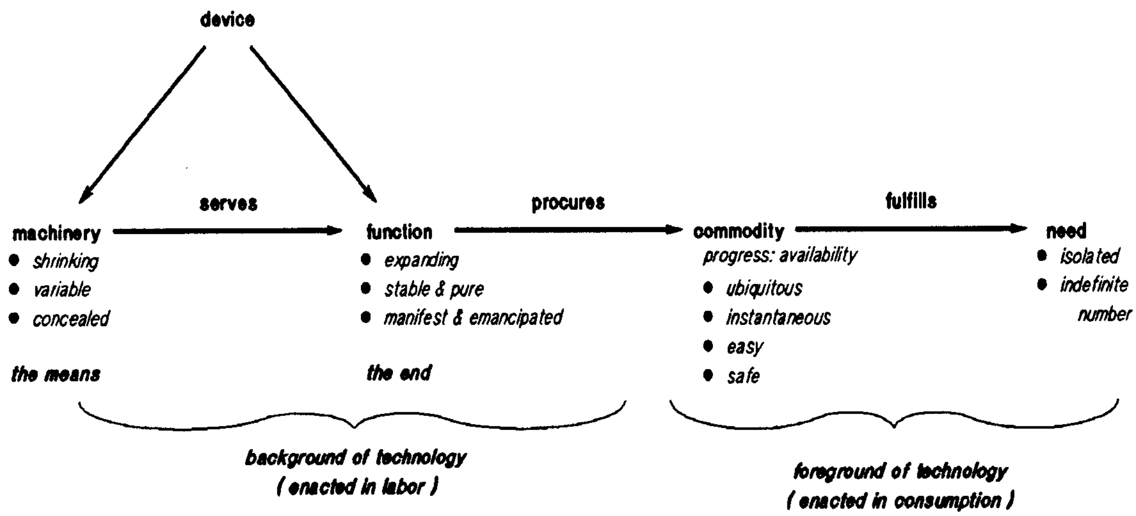

Figure 6.1: The Pattern of Technology.

The background of technology is enacted in labor and behavior becomes functionary, supported by the pervasive and persistent influence of technological background expectations. The machinery which serves the function of the device is ever shrinking, variable, more complex, and concealed which allows the function and its commodity to become more prominent. The function itself is manifest, ever expanding in prominence, and relatively stable in definition. As function and need become ever more sharply defined, they proliferate in an endless, if more trivial way.

And finally, the device paradigm itself has a recursive character to it through which the pattern repeats itself in a nested way throughout the machinery of technology. The paradigmatic pressure for automation is ever present.

Implications for Aviation Safety

The paradigm of technology that we have discussed above is descriptive, not normative or evaluative. Let us consider this paradigm and the context of aviation safety in two respects. First, as it relates to the promise of technology, do we see the pattern that we have developed above? Second, how does the pattern of technology manifests itself in the context of technological progress and advanced aviation systems? What is the potential for the ironic turn of mature technology to usher in its own unique pitfalls for flight safety?

The Promise of Technology

As a mode of transportation, the technology of flying has made way for the conquest of time and space on our planet. Our forefathers of just the past century traveled arduously across the country over periods of time measured in weeks, if not months or seasons. The notion of routinely traversing the continent, from New York to San Francisco, in five hours or less would have been unfathomable to them. In fact, the word 'travel' used to be *travail,* Middle English *travailen*, to toil, to make a toilsome journey; from old French *travailler*, to work hard, to labor, from Vulgar Latin *tripaliare*, to torture. [270] Journey involved physical exertion, pain and discomfort.

Flying has essentially liberated us from such toil, if not reduced it to a few hours of mild discomfort due to prolonged sitting, from which we are distracted through inflight services and movies. Flying has also provided for an enormous enrichment of our lives by shrinking the world to the point that we can experience its great wonders directly. We can view the great works of art and architecture of earlier periods. We can, if we choose, engage different cultures directly and become better world neighbors through better understanding. We can experience the great natural wonders of the world. And, of course, commerce with all parts of the world has been enormously facilitated.

Do you see the pattern of availability? This device, called aviation, has procured for us the commodity of rapid transportation, which fulfills our need to be at any place, any time of our choosing. It's success is measured in the ubiquity, ease, and instantaneity of the commodity; and in its safety.

Early flight was anything but safe. The airplanes themselves were unreliable, but more importantly, the environment was extremely hostile. Weather was unpredictable and certainly not under our control. Not only did clouds, for example, affect our ability to control the machine, what with disorientation, icing and so forth, but navigation was impossible which put flight travelers at great peril for encountering terrain or simply getting lost and perhaps running out of fuel.

But there is differential selective pressures for the various aspects of availability and this is a ball that Borgmann did not pick up. The pressures of ubiquitous and instantaneous availability, manifested themselves in production pressures which were far greater than those of safety. One of the early civilian users of the airplane device was the U.S. Air Mail Service, founded after World War I in 1918. In his historical summary, Perrow writes:

> Whatever it was that was so vital to transport quickly, it was delivered at a high cost. Life expectancy for a mail service pilot was four years. Thirty-one of the first forty pilots were killed in action, trying to meet the schedules for business and government mail. [271]

After a strike by the pilots over safety, more discretion was allowed for pilot judgment over the local Post Office field manager and conditions improved some. Yet, Perrow continues,

> ...there was a forced landing every twenty hours of flight. The demand for fast mail delivery (or the challenge to the Mail Service) led to the Night Transcontinental Air Mail Service shortly thereafter, using bonfires lit across the country and flare pots at the many landing fields. One in every six air mail pilots was killed in the nine-year history of the service, mostly from trying to fly through bad weather, such were the production pressures.

This function -- rapid transportation -- which in the beginning depended solely on the machinery of the airplane, created its own needs for more machinery and ultimately a complex aviation system as more and more commercial demands were placed on the opportunities the technology opened up. The early machinery carried with it its own source of suffering through risk of injury and loss of life. And the conquest over such suffering we can certainly view as part of the fulfillment of the paradigmatic promise of technology. We have seen the conquest -- even domination -- of nature in our ability to fly under all kinds of weather conditions; either through it or to be able to "see" our way around it.

Commercial aviation has expanded astronomically and safety has been a key component of its availability. The death risk per flight is now one in eleven million for U.S. domestic airliners and this represents a four-fold improvement since the early 1970's and a 10-fold improvement since the early 1960's. [272] Technology has "fixed" many problems in aviation, but how far can it take us? Will technological progress usher in more of its own safety problems? Above we have discussed paradigmatic pressures for automation. What irony does the progressive maturity of this technology present us? What about the differential selective pressures for the various aspects of availability and the influence of the technological background expectations? What can we expect in terms of the relative priority of safety?

Technological Progress

Availability

The extended promise of technology is one of liberation from burdens and constraints through a principled approach that is based on scientific insight. Commercial aviation is paradigmatically no different than any other *device*. There is an enormously complex *machinery* that serves the *function* of providing rapid transportation. There is persistent pressure to fulfill the customers' *need* of rapid transport from one point to another without burdening them in any way. This requires that the function, rapid transportation, be fully *available*. It must be *easily* accessible, simple for the customer to procure; from reservation, to ticket purchase, to airport parking and sheltered boarding, and on and on. The procurement process has become ever less demanding and burdensome and has been facilitated with more ease and simplicity for the traveler. We strive for it to be *ubiquitous* or omnipresent and *instantaneous*. Everyone would like a direct flight from their own departure point to their own destination point, whenever they desire to travel. Over the years, constraints on achieving this have been progressively reduced. On some shuttle routes, advertising tells us, you are never late for a flight, only early for the next one since they depart every half hour. Airspeeds have increased over the years which has reduced travel time. Customer tolerance for flight delays caused by air traffic, weather, mechanical failure or whatever reason, is low. We don't want to hear that the flight is fully booked and there isn't another one for several hours. We demand availability. And, of course, we expect it to be *safe*. Depending on the risk level one perceives, the option for instant security is available at the airport through the flight insurance vending machine.

Such pressure for full availability of the final commodity imposes paradigmatically recursive pressure for availability through all aspects of the commercial aviation machinery. Of the four essential characteristics (instantaneous, ubiquitous, easy and safe), the first three are tangibly and immediately experienced every time we place demands on the function. Of those three, the first two -- instantaneous and ubiquitous availability -- predominate over ease of operation and maintainability. This is because these "ease" aspects of the recursive devices of the machinery are only experienced by the operators. We will explore paradigmatic reasons behind this dominance hierarchy in the next chapter.

Safety is unique in that it is experienced through the lack of events (accidents, mostly) which are rare. Our cognitive framework is different for safety. We perceive flying as safe because we don't *experience* a continual stream of accidents or other unsafe events. The occasional event changes this perception temporarily, perhaps, if it hits close to home -- family member, location, etc. -- but, overall, safety has historically received the lowest priority of our concerns for availability. In fact, safety is obsequious to the other aspects of availability and their subsequent pressures and expectations for productivity and efficiency. These have overwhelmed the expectations for safety. Concern for safety seems rooted not in concern for loss of life, but in concern for continued availability of the commodity. It has taken major externally induced disorders such as a record of severe accidents, strikes, consumer advocate groups, and regulatory and political pressure to raise the priority of safety.

This is paradigmatic of technology. It is not a recondite fact; we do not have to be technologists to realize this. The auto industry, for example, exemplifies this well, as we know historically and from daily news items we have read over the years and continue to encounter. The opening sentence of a recent article states: "For years, automobile manufacturers have told us that safety doesn't sell." [273] The article goes on to describe how life-saving anti-lock braking systems, available on expensive European autos since the mid-70's, are only now at the beginning of the 90's, expected to be options on something other than luxury cars. Air bags were invented almost three decades ago and were referred to as "people savers." The technology has been commercially viable for at least half that time. For 20 years the industry fought air bags, claiming they were too expensive and people weren't willing to pay for them. In fact the claims about "leading the industry" being made in commercials right now by Lee Iacocca ("some things ya don't wait for") is such a joke that Garry Trudeau made a mockery of it in Doonesbury! [274] Iacocca was one of the biggest opponents and fought the requirement vigorously for over 18 years. These are highly reliable devices which halve your chances of being killed or seriously injured in a major car accident. Finally, just this year, automakers are required to have passive restraint devices (air bags or automatic seat belts, with air bags encouraged[64]) installed on the driver's side of all new models; incredibly, though, the driver is the only one afforded such regulatory protection. The major factors that brought about this change were consumer advocate, Ralph Nader, and Elizabeth Dole, the Secretary of Transportation. [275]

With respect to flying, I mentioned earlier that pilots of the early air mail operation had to strike to have some control over the conditions under which they were forced to fly. We tend to shake our heads at such examples; but, examined from a broader perspective, we can see that they are paradigmatic, even of an industry which we perceive as one of the safest. Yet we continue to see the obsequious nature of safety. It is servile to concerns of productivity and efficiency, with significant improvements coming primarily when those aspects of availability are threatened. Recall the legendary safety problems of the DC-10 (which became referred to among the pilot community as the "death-cruiser 10") and the resistance McDonnell Douglas exhibited to design changes which would fix the problems. It took four accidents and the loss of hundreds of lives before they implemented a design modification -- an engineered safety device to prevent asymmetrical slat retraction, which cost only a few hundred dollars. The company had claimed the chance of the combination of events which would render this a problem as one in a billion. The problems with the cargo door, another design issue, were known as early as prototype development and ground testing, and through early recorded maintenance difficulties. Neither the company nor the FAA seemed concerned. Even after the first door blew out and the NTSB recommended that the FAA mandate a redesign of the door, it was decided not to thoroughly redesign the door, opting instead for the money-saving solution of adding a simple plate to the door. This was thought sufficient by the head of the FAA and the head of Douglas aircraft. Even the simple installation of this "fix" took most airlines over 9 months to complete. This fix was also lacking human factors attention; the door was complicated and difficult to operate. All of this eventually contributed to a system accident, one of the worst in aviation history, with the crash at Paris of a Turkish airline DC-10. [276]

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64 They are also more economically feasible for the manufacturer.

The airliners, striving for availability, productivity and cost efficiency are under pressure to keep planes in the air at all costs. Eastern Airlines was charged with inadequate, in fact conspiratory failure, in their airplane maintenance. This involved radar, landing gear, autopilot, instruments and even the substitution of faulty gauges for faulty gauges without the pilot's knowledge. The FAA stated it hoped the problems were unique to Eastern. [277] But with higher fuel costs, debt servicing needs and less people flying, airlines are in terrible shape and the pressure to cut corners will continue to exist.

Such pressures are not unique to commercial enterprises. Although it is certainly the desire of all organizations to prevent accidents, the actual level of safety compared with the perceived level of safety is paradigmatically eroded by productivity and efficiency goals. The space shuttle *Challenger* disaster was no exception. NASA's administrative structure prioritized cost saving and meeting deadlines over safety through its incentive/award fee contract system.

> Absent a major mission failure, which entailed a large penalty after the fact, the fee system reinforced speed and economy rather than caution. ...so long as [contractor] management is convinced that a festering problem like the [O-ring] seal problem is not likely to cause mission failure, there is little incentive for the company to spend resources to fix the problem. ...Even the possibility of contract loss appears to have reinforced production interests at Thiokol, not safety. ...Thiokol managers approved the launch over engineering objections because launch delay might jeopardize the company's ongoing contract negotiations to continue producing the solid rocket booster for NASA. [278]

There is no evidence that sanctions were used at all to enhance safety compliance at Morton Thiokol prior to the *Challenger* launch. NASA's central goal is U.S. supremacy in the international competition for scientific advance and military supremacy. Innovation, mission productivity *and* safety are required to achieve that goal. But Vaughan's research has clearly shown that even an elaborate internal and external safety regulatory environment succumbed paradigmatically to other availability pressures. Now that the catastrophe has occurred, however, availability has been severely disrupted and priorities have been refocused on safety. Through the rest of the century, at most 12 flights a year are planned, down from a pre-*Challenger* goal for 1990 of 24, which was half of the original number initially envisioned by NASA. The change in focus is highlighted by the statement of a current NASA administrator: "Whether it was a misperception or not, the agency had the notion that what the government, what the country wanted us to do was to fly the space shuttle a lot, as fast as we could fly it." Now, continued availability means the organization and the shuttle program simply cannot afford another such disaster.

One space policy director stated: "They're still betting the organization every time they launch." [279] In fact, the continued threat to availability is very real -- risk analysts place the odds of disaster at one in 100 shuttle flights; others say even several in 100. The "very real possibility of losing another orbiter in the near future" has led the Bush administration's space advisory committee to recommend a reduction in its dependency on the shuttle by procuring an unmanned heavy lift booster for all missions except those requiring astronauts. [280]

Such paradigmatic pressures are pervasive. In Chapter 1, I noted that to the FAA's own admission, the development and application of new aviation system technology in ATC and flight systems has been primarily focused on increasing traffic capacity of the National Airspace System and economic efficiency of aircraft operation instead of flight safety. Perrow's investigations have led him to assert, however tentatively, the hypothesis that "the air transport industry (aircraft manufacturers and the airlines) supports safety regulations and requirements primarily when the increase in safety permits an increase in production efficiencies, and that the FAA concurs in this strategy." [281] He is not claiming that the industry is against safety, since some level of safety is an obvious prerequisite of the system. Only that the paradigmatic pressure for safety takes a lower priority; that, contrary to industry rhetoric, no one is making much of an independent or extra effort to protect the lives of employees, customers and innocent bystanders.

> [The industry] will voluntarily undertake safety modifications primarily under two conditions: (1) when the modifications make increases in production efficiency possible (building more economical aircraft and engines, for the equipment side of the industry, and increasing density and decreasing operating costs, for the service side) and (2) when they can be added to new aircraft without significant cost, especially if there is fear that a retrofit of the equipment might be required by public pressure (largely through Congress) or (more remotely) by FAA requirements. This means that voluntary safety modifications or additions will not be made simply because there is evidence they are needed. The industry will concur in and not protest and delay *mandatory* safety efforts primarily when these increase efficiency of the system (including higher utilization by the public). [282]

Perrow gives several examples to support his arguement. [283]

In fact, not only does safety get lower consideration than the other aspects of availability, when availability runs up against constraints safety margins originally thought necessary become perceived as an opportunity to relieve the other pressures. That is, safety gets viewed as a threshold constraint, beyond which we need not concern ourselves. Safety margins represent a well of opportunity, delimited by boundaries which can be technologically mined for the purpose of addressing the demands for the more immediately experienced traits of availability. A good example of this is the excellent risk study by Altschuler and Elsayed, sponsered by the FAA [284], which examines the possibility of increasing airport capacity by reducing separation requirements for aircraft on ILS approaches to parallel runways under instrument meteorological conditions. This would allow the handling of more aircraft per unit time, increasing the availability (at least tangibly experienced aspects) of the commodity "rapid transportation." The justification is that of constraints to availability: "Air travel delays resulting from limited airport capacity are one of the most significant problems facing the airline industry and the Federal Aviation Administration. ...Unfortunately, the presence of land acquisition costs and terrain constraints, as well as the potential for social and political resistance, renders [the construction of new airports or the expansion of existing facilities] virtually infeasible." [285] Even NASA is mining the safety margin put in place after *Challenger* for cost reduction. A high level administrator states: "There are now so many safe-guards on shuttle flights that NASA is considering eliminating some of the double-checking and triple-checking of items ...that would reduce shuttle operating costs by as much as one-fourth." [286]

Functionalism and Loss of Context

The paradigmatic drive for availability manifests itself through technological functionalism. As full availability requires the full and exclusive termination of function and need without disturbance or presentation of other relations, the machinery shrinks and recedes from our frame of reference, ever more concealed and forboding in its complexity. The function simultaneously becoming manifest in its prominence and purity, emancipated and autonomous of the background machinery of the device.

With respect to rapid transportation, "Beam me up, Scotty," comes to mind as a paradigmatic end.[65] Instantaneous, easily procured by the traveler, ever present in its availability and safe(?)! The machinery of the device, is beyond even our imagination, let alone our comprehension, just as jet airplanes would have been to those cross-country travelers of the last century.

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65 If you have been culturally deprived of the opportunity to watch *Startrek*, you won't be able to relate to this example.

En route to such purity of function, we must procede through the more mundane standards of our current modern world. Technological functionalism has been enormously succussful in procuring this commodity we call flying. Needs have been radically isolated and transformed as functionalism has recursively and pervasively penetrated and disolved the boundaries, barriers and constraints to availability of the end commodity. Function-need pairs proliferate in an unbounded way, ever more sharply defined, meeting at a purified point of singularity, isolated from their context.

For an illustrative example, consider the incredible technological progress in navigation. Where pilots once found their way by bonfires lit across the country-side at night, the problem of navigation has become extremely refined by the continual isolation of needs and availability of functions to fulfill those needs. The recursive availability of the functions calls forth new innovations in the machinery that serves up these functions. The en route positional information is procured to incredible accuracy by such devices as ground based VOR's and DME's, airborne inertial guidance systems, and geosynchronous satellite navigation systems. Whereas the night airmail pilot, with his head out the window looking for bonfires, was navigating in a way that was intimately engaged with the context of navigation -- time of day, weather conditions and so forth -- the function of navigation has been isolated and refined to the point that positional information is available, in the case of INS, independently of any other context.

So what? That seems not to create problems but solutions! The need to correctly position the airplane has been fully terminated by an autonomous function. The destination end of the navigation system is the precise vertical and horizontal alignment with the runway. Again, we have devices that have provided enormous capabilities for all weather availability of landing opportunity at the planned destination point. Instrument landing systems (ILS) and their various refinements, and the newer microwave landing systems (MLS) permit precision landings independent of weather; in fact, independent of the pilot's physical flying capability. It is not humanly possible to fly an approach as precise as a computer can, thus under the more restrictive weather conditions it is actually required to make the approach under computer control. The landing of the aircraft must be automated. The function of safely landing the airplane under such conditions isolates its own set of needs to be served by a multitude of sophisticated devices. But again, the design and operation of such a system is radically isolated from the context of the weather itself as well as other constraints it might impose.

One constraint mentioned above is the limitation such conditions impose on airport capacity, particularly when airports which employ multiple runways in good weather are restricted to one runway when weather worsens. This constraint isolates another need, the procurement of greater capacity. At airports with parallel runways, equiped for independent simultaneous ILS approaches, such capacity can be procured from the safety margin through a technological device called 'quantitative risk assessment.' The reduction of the current minimum separation requirement is a "practical alternative to the addition or expansion of existing facilities." [287] It is true that original separation standards (runway and aircraft) were set arbitrarily to meet existing constraints and then justified by FAA procured risk assessments. At first, the standard of 5000 feet between runway centerlines was based on two risk assessment studies in the early 60's, which accommodated O'Hare, Los Angeles, Atlanta and Miami airports which had existing parallel runways spaced accordingly. By the late 60's, the Department of Transportation felt that the increasing air traffic volume necessitated a further reduction in runway separation requirements. Based on an additional risk assessment study, the FAA reduced the required runway spacing for independent simultaneous parallel instrument approaches to its current standard of 4300 feet which "was chosen to allow additional simultaneous approach configurations at Atlanta and Los Angeles." [288]

It is also true that the margin of safety is related to the capability of the landing system devices (airborne and ground). The system thus isolates and defines further needs, in particular for the availability of information. Altschuler and Elsayed refer to a study, for example, that concluded "simultaneous ILS approaches with 3400 foot runway spacing was feasible if it is supported by a radar having an update interval of no more than 2 seconds and an accuracy of no less than 2 milliradians (the current standard is approximately 4.3 seconds and 3 mrad, respectively)." [289] All such systems analysis studies, of course, depend on arbitrary assumptions about system states such as worst case blunder scenarios. The particular study that produced the 3400 foot recommendation produced unacceptably small miss distances even at the current standard for runway spacing. Altschuler and Elsayed remark that, these authors "reasoned that this blunder scenario, initiated by an unexpected 30 degree turn toward the opposite runway in the presence of traffic, was probably unrealistic and too severe for use as a test or design consideration." [290]

The point in all this is not a critique of quantitative risk assessment [291], nor Altschuler and Elsayed's excellent literature survey and proposed methodology; it is merely to drive home the point that it is paradigmatic of technology. The functions of such devices becomes severed from their context, as does their evaluation. Through automation we can vertically and horizontally navigate and control the aircraft from take-off through the climb, level-off, descent, approach, the landing flare and runway breaking under conditions of zero visibility, without human intervention. And, we can squeeze more airplanes onto the ground simultaneously, all of this addressing needs that are removed and isolated from their broader context. We have isolated these needs, defined more refined functions to fulfill them and invented more complex machinery to serve up those functions. Severed from their context, these needs become thought of, analyzed and fulfilled without further presentation of other relations.

To draw this example to a poignant conclusion, with decades of technological progress that have partitioned, transformed, created, isolated and fulfilled an indefinite array of needs related to the availability of flight in inclement weather, sadly, we have neglected safety on the ground almost entirely. In the aftermath of the December 3, 1990, ground collision at the Detroit airport of a DC-9 and a Boeing 727 that killed 8 people, an NTSB spokesperson stated that one of the most serious and over-looked problems of aviation safety is ground congestion at U.S. airports. [292] Even in good weather, one ground controller said, directing traffic on the ground is like "a circus trainer trying to keep 15 lions on their chairs at the same time." In this tragedy, airplanes were attempting to taxi and take off in fog so thick, the pilot could not see a distance even the length of his airplane. Ground control had handed the 727 over to local (air) control for clearance onto the runway and takeoff. The DC-9 reported to the ground controller that he could not track where he was on the taxiway with respect to the charts, that he was lost and may, in fact, be on the active runway. Of course, under these dense fog conditions neither the local controller nor ground controller (who are virtually right next to each other in the control tower) could verify the location of either airplane. By the time the DC-9 reported being lost to the ground controller, the 727 had already been cleared for take-off by the local controller and had commenced his takeoff role, resulting in the collision. Obviously, the DC-9 was not supposed to be on the runway.

Human error? Pilot? Controller? Could someone have foreseen such problems? Afterall, the visibility conditions did not prevent a legal takeoff. Separated from their context, the needs of takeoff and flying in such conditions had been functionally accommodated by the array of associated devices. Hundreds, if not thousands, of engineers must have been involved in their evolution over time. How could ground control be so ignored? Dr. John Lauber of the NTSB stated that ground (and runway) incursions, as they are called, have long been a sensitive issue. The most tragic was the collision of two 747's in the fog at Tenerife, Canary Islands, in 1977. Since then the number of incursions continues to rise. The NTSB, Dr. Lauber emphasizes, can only make recommendations to the FAA; and they have been concerned with the lack of sufficient progress the FAA has made to date. After the NTSB testified before congress in March, 1990, to this effect, there are indications, he said, that new schedules and resources have been set. However, some controllers doubted even new technology would have helped much in this case. The issues are so sensitive that attempts to obtain on-camera interviews from controllers or any FAA administrators were unsuccessful.

The NTSB emphasized that with pressures on the system due to the growth in projected traffic and congestion, the problem will only get worse. They would like to see some sort of automation explored. Ironically, some controllers believe that problems in the sky are worse than on the ground and they are concerned that the diversion of resources to ground control, which will be accelerated by this incident, will prevent other needed improvements for better airborne radar. But, the most critical problem, they say, is the lost margin of safety due to reduction in staff that air traffic control has yet to recover from -- yet another difficult aspect in the context of aviation safety.

Complex and Receding Machinery

We have seen in the pattern of technology, that the machinery of the device is indefinitely variable, becomes increasingly complex, and is ever more concealed as it shrinks and recedes from our cognition and view, while its function becomes more prominent and pure. The ability of people to understand the machinery of the device and its behavior becomes more forboding for all but a few technical experts. Operators (pilots and controllers, for example) become mere functional consumers of commodiously available information. In complex, high-risk, sociotechnological systems, the paradigmatic pattern of normal accidents is based in the cognitive paradigm and exacerbated by the technological paradigm.

Recall from Chapter 4 that normal (system) accidents were defined by multiple and unexpected interactions of component failures. The cause of such accidents is to be found in the complexity of the system. It is impossible for designers to foresee, understand and prevent all of the possible failures and their interactions. When they occur, interactions are not only unexpected, but incomprehensible for some critical period of time. The more complex and concealed the machinery of the device, the more it is removed from the cognitive framework of the operator. Thus, the greater the chance that when multiple component failures occur, which they eventually will with certainty, the greater the chance of unanticipated interactions that literally cannot be seen, or even if seen, are not understood or even believed. With tightly coupled systems such as those in aviation, the risk of unrecoverable catastrophy increases.

The paradigmatic implications for safety are obvious. We can see that a "pressure" toward system accidents is paradigmatically embedded in technology. As the size and complexity of systems increase, and the number of diverse functions they serve increases, and with increasing functional coupling to other systems as automation progresses, we can expect less and less slack or buffer in the system. We can also expect more and more incomprehensible or unanticipated interactions to occur in these ever more tightly coupled systems. The human crew, which should be a buffer between subsystems, are more and more contextually disengaged as functionalism has dissected the substance of piloting into needs, and functions which fulfill those needs. Computers can run the airplane more efficiently than humans, or make for greater productive capability, or allow operation in more hostile environments. Crews are under continual paradigmatic pressure to operate the system at the limits. The more piloting becomes functionalized, the more devices can take over the performance of those functions. Disengagement of the crew leads to diversions and distractions and a cognitive framework which is ever more inadequately equiped to deal with unexpected failures and their interactions. Earl Wiener writes: "The burning question of the near future will not be how much a man can do safely, but how little." [293] This makes these sophisticated systems more vulnerable to unavoidable system accidents.

As system failures are contemplated in the design phase or as accidents actually occur, apodeictic functional analysis determines which devices failed and how the failures functionally interacted to produce the system accident. Engineered safety functions and devices, and other technological fixes provide additional buffer and confidence of safety and, in fact, may resolve the observed problems. But technological fixes, themselves, increase interactive complexity and tighten the coupling, thus they do not deliver reprive from the paradigm.

To illustrate these points, let us briefly consider some aviation frontier research in intelligent interfaces which is expanding the envelope of aviation technology, with artificial intelligence in the cockpit.[66] My objective here is not a technical critique of this work, which represents some of the most sophisticated and well funded technological efforts thus far, but to describe it in its paradigmatic context.

The work is that of William Rouse and his colleagues. Their ambitious goal is to develop a comprehensive intelligent interface architecture for operators of complex systems [294] and their prototype development platform is that of a "Pilot's Associate" for the fighter cockpit, of which they have considerable domain expertise. The conceptual design, much of it speculative because of the lack of maturity of much of the technology involved, would guide future research on specific technologies and devices needed to implement it. The Rouse group acknowledges the paradigmatic problem of increasing system complexity due to advances in computer and communication technology; and, that this results in overwhelming information overloads with the inevitable result that anticipated performance benefits from such sophisticated technology are not realized. Their belief, though, is that "the same technology that has precipitated this problem may, in combination with other technologies, be able to contribute to potential solutions to the problem" [295], and their system architecture is a concerted effort to that end. It is also significant that they recognize the paradigmatic nature of automation technology, at least in one sense. In discussing automation philosophy they acknowledge that one of the most ubiq-

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66 The development domain of this work it that of the fighter pilot cockpit. However, the implications are much broader, as much of advanced aviation technology works its way out of the military environment into other domains. Consider, for example, head-up displays.

uitous (albeit often only implicit) approaches emphasizes "utilizing as much automation as is technically feasible, with human operators taking responsibility for all functionality for which automation is not [technically] feasible." They say such an approach is understandable, but reject it as a guiding philosophy, stating it is "increasingly unacceptable [because] the technology that is driving automation efforts becomes more likely to be incomprehensibly complex." [296]

Their intent is to avoid disengagement of the operator from the system by utilizing automation as a backup, with "automation invoked only when either anticipated operator performance is unacceptable or the operator chooses to relinquish control, ...[keeping the operator] very much in charge." [297] They espouse a support system concept which is based on an operator-centered design methodology for intelligent human-machine interfaces and an "adaptive aiding" automation philosophy. The user-centered design approach is well acknowledged in the human factors (and decision support system) design communities to help foster user acceptance of the technology, if it actively enlists representative user input and perspectives in the design phase, which the Rouse group has done. The automation philosophy uses automation to support, rather than replace human operators, which nonetheless, implies a very complex intelligent interface system that "rivals or exceeds in sophistication other task-oriented intelligent software subsystems envisioned for complex systems." [298]

As noble as these goals are in addressing some of the pitfalls that we have discussed regarding the paradigm of technology, it does not escape it. The functions that the enormously complex machinery of this device is intended to serve are associated with overcoming human limitations and enhancing human abilities "so as to extend the range within which humans can remain in control of the technologies underlying their systems." [299]

The nucleus of this system is an operator model for assessing and predicting operator states in order to "know" when and what type of aiding the operator needs and how it should manifest itself. The model is based on a functional partition of the human operator and it maintains and updates current and predicted estimates of elements of operator state, including: activities, awareness, intentions, cognitive resources, and performance. All of these require some sort of machine analogy modeling of the human, including a resource model, performance model and intent inferencing model. The goal of adaptive aiding is for the operator to remain efficiently in control; that is, to provide aiding that "adapts to current needs and capabilities, in order to utilize human and computer resources optimally and, thereby, enhance overall performance." [300] Its greatest utility is perceived to be when systems are dynamic and running at such a high rate that the aiding will intelligently adapt, presenting appropriate information and allocating tasks dynamically to human or computer, based on an understanding of the conditions. "The primary innovation of adaptive aiding is not adaptation per se but the possibility of aid-initiated adaptation." [301] Thus, we have the need to understand and predict human thinking and behavior in order for the device to know when to initiate aiding. "Virtually all of what is outlined in [adaptive aiding] is highly dependent on being able to measure and predict human performance, as well as assess and predict human awareness and intentions relative to the task queue." [302]

This extraordinarily complex system with its high level of system interconnections, and multiple branching, and multitude of conditions and exceptions, exhibits extremely tight coupling. Further, it is expected to provide its greatest benefit operating at (even expanding) the limits of capability in a hostile, dynamic environment where buffer is essentially non-existent. Even granting Rouse and company's insightful identification of potential pitfalls to be addressed technologically, the potential for system accidents appears enormous. As one walks apodeictically through their system architecture and supporting research and arguments, the logic and design concepts present themselves as sound and thorough, indeed a reasonable and sophisticated approach to a tough problem. But examined in its paradigmatic context, it presents monumental concerns for safety. These are rooted in the coupling, complexity and incomprehensibility of unforeseen interactions that are in fact amplified by such a system. The paradigmatic irony is that, in its attempt to expand human abilities and overcome human limitations, it will if fact grossly exceed them.

Consider, for example, the pilot's cognitive framework and the potential for incomprehensibility when a paradigmatically concealed machinery is adapting itself and the commodities (information, decisions, actions, etc.) it presents to the pilot based on models of what it "guesses" the pilots behavior and intentions are. It may correctly guess much of the time, but that is not what the notion of normal accidents is referring to. The Rouse group believes that the legendary difficulties of comprehensively modeling operator behavior and performance, such as the need to answer a wide variety of types of questions, can be surmounted by adopting a "matrix of models" approach based on a functional dissection of the operator. Different operator tasks (scanning, recognizing, problem solving, regulating, and steering, for example) are best modeled through different machine analogies (signal detection theory, information theory, queueing models, servo-mechanism models, regression models, etc.). Thus these human performance models become the elements of the matrix, with one dimension being type of function (task) to be performed and the other, types of performance metric (speed, accuracy and others specific to the task). What remains then is for the system to intelligently select from the matrix the abstract model that is relevant to the contextual reality. The "performance model knowledge source" is rounded out by combining "the relatively context-free approach embodied in human performance models ...with highly context-specific expert system formulations." That is, heuristics will specify "when and how particular models apply, as well as appropriate parameter values for the applicable models." [303] It is expected that these heuristics will enable predictions of multitask performance, although the authors acknowledge that, considering the possible combinations and contexts, they may never be able to fully validate it.

This approach has the trappings for normal accidents -- in fact, it is obviously inviting such accidents. It has shallow simplistic models of humans based on machine analogies that will interject information, decisions, recommended actions, etc., into the pilot's cognitive framework at the moment when his ability to perceive any incongruities is at its lowest due to the extreme environmental stress he is under. It is exactly the time to have the equipment shut up and let the pilot operate from his own expert cognitive framework which he has developed from experience. We will examine the implications of that further in a discussion of expertise and experience in the chapter on the paradigmatic nature of the MAC 40641 accident.

Borgmann writes that man is substantively and paradigmatically *deep*.

> One may call a thing shallow if only a few of its scientifically and technologically specifiable traits are significant. One trait or function is predominant; all others are arbitrarily exchangeable and progressively eliminated. ...We must ...learn to realize that if we increasingly surround [man] with shallow things, he will become shallow also. [304]

The pilot in such an airplane would be ever more functionally severed from his context through the adaptive presentation of information based on machine-perceived needs, heuristically guessed from machine models of his behavior. We can expect his cognitive framework to become ever more shallow, distracted, confused and inadequate to comprehend the way such "aiding" might interact with reality.

Technology as a Substantive Guiding Force for Safety

I believe we have seen that technological functionalism lacks orienting and guiding power with respect to aviation safety. This is merely a manifestation of Borgmann's thesis on technology in general. Such a statement undoubtedly would seem to blaspheme engineering[67], for the essence of engineering is surely functionalism; it is what sustains the paradigm of technology. Functional analysis and the design of machinery to serve up the functions and commodities they procure, are the way in which engineering and other technological specialties serve society in a purposeful, practical and utilitarian way, as the essential background of technology. And besides, engineering is *fun* in an experiential way for those of us who enjoy the intellectual challenge of analyzing problems, solving puzzles, developing novel functions, and inventing new machines. [305]

Nonetheless, it is clear that, contrary to its self-perception, we cannot look to technology and engineering as our source of orientation and guidance concerning aviation safety. That is a paradigmatic reality. It doesn't mean it *can't* come from engineers, per se; just that we should not expect it from the traditional education, training and socialization process engineers go through. What is appropriate technology, in the context of safety, conjures up moral disagreement within our culture and there seems to be no rational way of dealing with it. [306] We view the world through a framework that is technological through and through, leaving us wanting for some other kind of perspective. [307] Quoting William Barrett, Bella writes: "...our problem is that we are unconcerned to ask what the presuppositions of this technical world are and how they blind us to its framework." [308] Technological expectations, Bella continues,

> ...have too much shaped and constrained human discourse ...[Engineers] respond too defensively to criticism of technology. We take our technological backgrounds too much for granted. ...We have devoted little time to reflection. ...When the technological background dominates human activity, a "functionary" behavior results. [309]

Such functionary behavior, by which Bella means obediently fulfilling your expected role in the background machinery of technology, leads to an ideology of "technological guardianship." For example, technological guardianship arguments go like this: aviation involves enormously complex technology, understood by a rel-

67 And I am a highly educated engineer and proud of it!

ative few technical experts and people of higher positions in the aviation industrial-regulatory complex. They are the ones with the information, knowledge and authority, and thus the question of aviation safety is a functional need best left to them to fulfill. Bella writes that, in general,

> Technological guardianship holds the following fundamental premise: *the welfare and security of society increasingly depend upon the effective applications of modern technology through the organized work of qualified specialists and managers.* ...Technological guardianship claims that modern technology has become so complex that it can only be assessed by the most highly qualified experts. Public practices and ideals that are not consistent with such views are dismissed as "unrealistic." [310]

The ideology of technological guardianship is one result of the systemic distortion of information and perception that is paradigmatic of organizational complexes. This constitutes the last of our four paradigms and we will now take it up.

Chapter 7

The Paradigm of Organizational Complexes: Adaptive Avoidance of Disorder and Systemic Distortion of Information

The last paradigm we will consider concerns a sociological phenomenon that is characteristic of organizational complexes. We live in a society of organizations; they are essential to the design, construction, maintenance and operation of the complex sociotechnical systems that constitute the infrastructure of our technological world. It seems obvious that accurate, timely and pertinent information is required to keep these systems running smoothly; that is, to fulfill their functional goals. But herein lies the problem.

The Goal Paradigm

Almost all definitions of organizations make the assumption that organizations are oriented toward a specific goal. [311] Organizations are part of the paradigmatic background machinery of technology; powerful, though recalcitrant, tools under the "control" of their masters. As a tool[68], the organization becomes a resource for the achievement of the goals and objectives set by those in power at the top of the organization. The organization is structured to divide the tasks needed to accomplish its goals and everyone performs his or her function to meet that end.

Such a description as this reflects a distinctive "rational model" of organizational behavior, wherein its proponents "see the managerial elite as using rational and logical means to pursue clear and discrete ends set forth in official statements of goals..." [312]. And this perception is perpetuated by the cognitive framework that has been instilled in us through our training and professional socialization -- it is the influence of the functional expectations that David Bella has referred to as our technological background[69]. For example, there is a strong perception that complex technological

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68 In fact, the word "organization" comes from Greek *organon* and Latin *organum*, meaning implement, instrument or tool.

69 See Chapter 5.

systems are designed and operated in this rational goal-driven fashion once the "value" issues have been argued out in the planning process. Thomas Sheridan, a well known MIT mechanical engineering professor who has done extensive research in man-machine systems and human factors engineering, recently wrote:

> The public believes that the process of designing the *technology* of large-scale systems, such as those for air transportation, communication, manufacturing, and power generation, is essentially objective, orderly, rational (even scientific), and somehow free from value conflict -- in other words, that technological design can be separated from social process. Even worse, many politicians, lawmakers, and systems designers/engineers also believe this because of their training or, one should say, mistraining. Systems engineers often claim to be designing value-neutral technology, letting the politicians, business and market forces, and the user public determine how the technology is used. ...Although most systems engineers have probably heard pleas to be more open to multiple perspectives and to seriously consider "the human factor," they still seem to move ahead naively. [313]

Virtually every functioning organization does have an *explicitly* stated mission with specific goals and policies. Yet, this does not accurately characterize organizational reality. Perrow believes it is those goals that are *implicitly* embedded in major operating policies and daily decisions of personnel that are most relevant to understanding organizational behavior. And these goals are dynamically shaped by particular problems or tasks that must be accomplished. Further, the goals pursued by organizations are multiple and generally in conflict. Even those that are agreed upon are often highly ambiguous and not operational, in that there are multiple routes to achieving them and it is often uncertain when or even whether they are actually achieved. Actual goals have an "emergence" property that is borne out by the actions of the organization as the "public or official goal" is factored into operational behavior. Finally, as a society of organizations, each organization (particularly larger ones) are part of an *organizational complex* in which "organizations are caught in a dense web of interdependencies such that they are also multipurpose tools for a variety of groups outside the organization as well as within it." [314]

The goal paradigm, whether goals are explicitly stated or implicitly operative, seems unable, however, to provide a cohesive and penetrating understanding of organizations and their behavior. Petro Georgiou has found this to be the case throughout a diversity of approaches to organizational analysis and studies of organizations that have appeared in the literature. [315] The fundamental flaw, he writes, "lies in its assumption that the goals of any group can effectively determine the operation of the organization." [316] Georgiou has examined the goal paradigm in its historical context and argues convincingly that the study of organizations has been "dominated since its inception by the conceptualization of organizations as goal attainment devices." [317] The primacy of the goal paradigm has been retained "not because of the insights it yields, but because it is embedded so deeply in our consciousness that it is a reality rather than a theoretical construct to be discarded when it ceases to enlighten. Intellectually exhausted, the goal paradigm has become a procrustean bed into which all findings are forced and even incipient counter paradigms absorbed, regardless of their promise of greater insight." [318]

Indeed, this framework has become the cognitively supplied context that has monopolized our view of organizations; but it has not brought forth an understanding able to cope with the reality of organizations. We have come to understand the organization as a "whole entity ...so superior that it is effectively divorced from the influence of the parts. The whole is regarded not as the product of interaction between the parts, but as determining them." [319] The essential thrust of Georgiou's counter is that organizations "can best be understood as outcomes of the complex exchanges between individuals pursuing a diversity of goals." [320] The individual is the basic strategic factor in organization. "Understanding behavior in the complex of relationships called 'organization' can only be based on ascertaining the rewards which various individuals pursue through the organization." [321]

The Adaptive Complex Paradigm

David Bella has developed a paradigmatic explanation of an emergent organizational behavior which is based on innate behavioral tendencies of the individuals working within the organizational context. [322] The organization can be seen as a "market place" in which incentives are exchanged among its contributors. [323] Through this process individual adjustments occur which sustain internal coherence. Disruptions and disorder tend to be perceived as adversely impacting the organization's ability to "keep the system going." The manifestation is that organizations, themselves, tend to behave in a way that avoids disruptions and disorder. Perceptions of the individuals who constitute the organization are systemically shaped to keep the system going. The resultant pattern that emerges for any organizational complex is the subtle but systemic distortion of information that does not depend upon the intentions of its members to deceive. Information becomes favorably biased as it is processed and filtered through the organization. This is the essence of Bella's information-distortion paradigm of organizational complexes. The phenomenon, however, has not gone unnoticed by the heads of organizations, themselves. Jeffrey Sonnenfeld, for example, presents an excellent study on the difficulties that leaders of organizations have in obtaining accurate information, and hence perceptions, even when their intent is to do just that, through the design of organzational structures to ensure it. [324]

Bella's paradigm relates the behavior of individuals (members of a complex) to the behavioral tendencies of an organizational complex as a whole. It incorporates a wide range of concepts which he has drawn from an extensive review of the literature in several disciplines. Its basic tenant is that an organizational complex is an adapting system that must constantly adjust to sustain internal coherence. Bella defines an *organizational complex* as "an open system of mutually reinforcing human behavior and perceptions that sustain and are sustained by extensive networks of information and resource flows that serve the maintenance and expansion of the system itself." [325] The concept is interorganizational in scope, but nevertheless an "organizational complex" refers to a system of organizations that undertakes coordinated actions and displays characteristic behaviors. Examples include civilian public works complexes, the military-industrial complex, the space exploration complex, the U.S. Air Force, and the commercial air transportation system.

For clarity, Bella partitions the complexity of his paradigm into a series of numbered statements. Without going into great detail, I have related some of the key aspects of these numbered statements below.

1.	**Local environment**	Each and every person within a complex is surrounded by a particular local (internal to the complex) environment that is sustained by the complex. The environment is the surroundings that instill and reinforce certain perceptions, practices, and expectations.
2.	**Behavioral influence**	A person's environment shapes his or her behaviors, actions, and decisions by sustaining (reinforcing, affirming, supporting) certain practices, perceptions, and expectations.
3.	**Information and resource flows**	The nature of each environment depends upon the particular flows of information (evaluations, instructions, reports, rumors, gossip, etc.) and resources (funds, personnel, supplies, equipment, etc.) to it.
4.	**Coupled system**	A network of information and resource flows connects a variety of local environments so as to make them mutually dependent.

5.	**Accepted expectations**	Although local environments are highly diverse and specialized, order is considered to be of primary importance and responsibility is defined in terms of the expectations of one's local environment and the need to sustain order. People accommodate to such expectations through education, peer pressure, role models, status, rewards, authority and other reinforcements in the administrative system. Thus competency, duty, and obligation become associated with meeting the expectations of one's environment and enhancing order.
6.	**Disorder**	A disorder is a condition (situation) within which a person encounters something (actual or potential) that is contrary, disruptive, or incompatible to the practices, perceptions, and expectations of the person's environment. It might include inadequate information, insufficient resources, unfulfilled ambitions, conflict between perception and expected practice, the prohibition of one's own ethical standards, or the perception that something is morally wrong.
7.	**Individual avoidance of disorder**	The experience of disorder motivates a person toward changes that might lessen or avoid the disorder.
8.	**Organizational adaptation to disorder**	A complex is an adaptive system that emerges from a history of human decisions that, in general, respond to disorders. The growth and spread of internally experienced disorders within a complex promotes alterations of organizational arrangements within the complex in order to eliminate the disorders that arise from incompatible arrangements.
9.	**System compatibility**	When arrangements within an organizational complex are more compatible, disorders are less likely to grow and spread. A general state of compatibility is one of reciprocal determinism, congruence, and mutual causality of arrangements; local environments are supported within which practices, perceptions, behaviors, and decisions are mutually reinforced through the networks of information and resource exchange that sustain the environments of individuals.
10.	**External environment**	The external environment of a complex influences compatibility by directly impinging upon the individual environments of members (thus influencing their perceptions and behaviors) and altering, sustaining, or withholding information and resource transfers to and from the networks of the complex. The environment influences the requirements for compatibility. For example, compatibility must accommodate such externally sustained influences as beliefs, values, customs, practices, observations, and laws.
11.	**Spread of disorder**	Organizational arrangements that are inconsistent with system compatibility tend to spread disorder through the complex and thus promote alterations.

12.	**Dynamic equilibrium**	An organizational complex will tend to adapt toward compatible system states within which the growth and spread of disorders is less likely to occur.

Thus a complex is not a deliberately designed, constructed and managed entitiy to attain explicit goals, but an adapting system that emerges from disorders. Goal statements will be contained within a compatible state because that can be effective in sustaining compatible actions, perceptions and environmental relationships. But to view an organizational complex as a deliberate structure to attain explicit goals is a mistake. [326]

The more a complex matures, the more its mutually sustaining arrangements dampen the impact of disorders and thus the larger the disorder required to motivate significant alterations of arrangements. Networks of authority resulting from patterns of compatible expectations emerge that serve to limit the growth and spread of disorders within mature systems. Mature states can vary, some more flexible and able to tolerate fluctuations better (higher threshold for disorder); others more rigid with a lower critical threshold beyond which disorders rapidly grow and spread throughout the complex. An abrupt restructuring can result or the complex might decay to a less mature state. It is at such critical points that the complex becomes more open to events and decisions that can have significant and long lasting effects on its emerging structure. It will find new ways to avoid or limit the disorders in the future.

Bella's model is clearly a paradeictic form of explanation. It does not seek cogency through apodeictic subsumption under laws and initial conditions resulting in "proofs" or detailed predictions. Rather it describes general behavioral patterns and tendencies of organizational complexes. Now we must consider its implications on the nature of information.

Through the motivating forces of expectations of internal environments and competition for limited resources [327], and the compatible arrangements that serve to limit or prevent the growth and spread of disorders, organizational complexes tend to shape the content, attitude, and meaning of information. Bella writes:

> People who respond to their local environment in an orderly and responsible manner can feel that their own behaviors, actions, and decisions are responsible, reasonable, and justified. ...They exist in a state of person-organization compatibility that sustains the perception that it is the right and moral thing to do. That is, they exist within a state of normative control by the organizational system. ...[Likewise] behaviors, actions, and decisions not consistent with the expectations of one's environment will tend to be considered as irresponsible, unreasonable, and unjustified. ...[Thus] compatibility places nonarbitrary demands upon information. [328]

To meet the requirements of promoting internal compatibility and securing the resources it needs, the complex adapts to sustain some information while excluding others.

> In general, compatible information that legitimizes the behavior and demands of the complex, justifies its needs and requirements, promotes nondisruptive (compatible, dedicated) service from its members and supports the needs of powerful interests meets these requirements. In contrast, noncompatible information that criticizes the behavior and demands of the complex, conflicts with its needs and requirements, promotes disruptive behavior from its members and fails to support the needs of powerful interests does not meet these requirements. One should expect a selective tendency toward compatible information. That is, a complex will tend to selectively collect, produce, and distribute information that promotes compatible (supportive, nondisruptive, conforming) practices and behaviors among its members and legitimizes its behavior and needs. [329]

Thus, in organizational complexes we have a tendency toward the distortion (self-serving selection, shaping) of information that *need not arise from deliberate deception or falsification by individuals*. In fact, Bella notes, it is important to emphasize that deliberate falsification would not be expected (though it certainly can occur covertly) as a general rule because it would likely result in ethical disorders. Nonetheless, the pressure exists for the selective collection, interpretation, distribution, and presentation of information that sustains favorable perceptions concerning the complex and its behaviors. Within the cognitive framework sustained by the local environment it would be unnatural for complexes to behave otherwise. This systemic distortion of information is a subtle emergent property that characterizes organizational complexes. The members do not perceive of themselves as inducing such biases. They work within a self-sustaining compatible internal environment and perceive that their own behaviors, actions, and decisions are responsible, reasonable, and justified. But the selective influence is nonetheless pervasive, persistent, and nonarbitrary. Undoubtedly the most profound example of such distortion of information is that which occurred throughout the military-political complex that tried to run the Viet Nam war. Bella presents and analyzes other examples from organizations participating in the preparation of environmental impact statements, the problems in NASA surrounding the space shuttle Challenger disaster, the Chernobyl nuclear reactor disaster, and he contemplates implications for the military-industrial complex, in general. [330]

Systemic distortion is not likely to be critically examined, scrutinized or exposed from within the organizational complex because of the disruptive influence on the organization.

> Individuals [within the complex] who might challenge a distortion are likely to become isolated and reprimanded (often by peers) for overstepping their authority and behaving irresponsibly. As long as responsibility is defined in terms of the expectations of one's environment and the enhancement of order, independent inquiry is not likely to arise particularly if it is potentially disruptive. Instead, people will be preoccupied with the tasks of their local environments. They will have little time, authority, or incentive to examine concerns that might disrupt organizational arrangements and activities. As long as information transfers are tightly coupled to resource flows, information is not likely to critically assess the system that provides the resources. Resources are not likely to support sources of critical information. As long as decisions tend to remove or prevent disorders, organizational arrangements that collect, produce, distribute, and display disruptive information are not likely to be sustained. [331]

Summary of the Paradigm

Virtually all organizations have formally stated missions, goals and policies. Just about everyone learns to understand organizations as structures which are designed to pursue specific spelled out goals, goals that are set in various ways by top management. This cognitive framework can be characterized as the "rational actor model."

However, this framework has not brought forth an understanding which is able to cope with the reality of organizations. An alternative framework appears much more fruitful in explaining organizational behavior. It is laid forth in the paradigm of organizations as adaptive complexes. No matter what their formal purpose, these complexes, which can involve several "formally defined" organizations, all demonstrate a common and pervasive tendency to avoid disorder. This is accomplished by the multitude of adaptations in the "local environments" within which the individuals of the organization operate. Local environments sustain and reinforce certain perceptions, decisions, and actions which minimize disorder. This is accomplished through adjustments in resource and information flows.

An outcome of this adaptive avoidance of disorder is the systemic distortion of information. Information is collected, filtered, processed, communicated, and interpreted in such a way as to favor those arrangements which are best able to avoid, limit, control and dampen the disruptive influences of disorder causing events. The fundamental character of this tendency toward self-serving selection and shaping of information is that such distortions occur naturally and need not arise from deliberate deception or falsification by individuals. Although such deliberate falsification does happen, the essence of this paradigm is not rooted in unethical behavior, but natural functionary tendencies of individuals just doing their jobs.

Consider the following "ode" as a humorous, if somewhat irreverent, tong-in-check illustration of how information can be distorted in ways that need not arise from deliberate deception, but nonetheless are self-serving and reflect favorably on the organization. This is adapted from such an ode that was floating around the lower ranks of the U.S. Forest Service in the late 1970s. This was a period of great disorder in this agency caused by new policy laws that entirely restructured the Forest Service's planning policy. I have changed the position titles to make it a little more "in context" with later aviation discussions. It ties in later on with a particularly disliked policy that the Military Airlift Command had in place in the mid 1970s. Keep a smile on, General, no offense intended.

Ode to the Integral Crew Policy

In the beginning was the requirement, and then the tasking.
And the requirement was without form, and the tasking, it was void.
And darkness was upon the faces of the aircrews thereof.
And they spake unto their squadron commander, saying,
"It is a crock of shit, and it stinks to high heaven."
Now the squadron commander spake unto the Wing Deputy Commander for Operations, saying,
"Its a crock of excrement, and none may abide the odor thereof."
Now the Deputy Commander spake unto his Wing Commander, saying,
"It is a container of excrement, and it is very strong, such that none may abide before it."
And the Wing Commander spake unto the Deputy Commander for Operations of the Numbered Air Force, saying,
"It is a vessel of fertilizer, and none may abide its strength."
And the Deputy Commander for Operations spake unto his Numbered Air Force Commander, saying,
"It containeth that which aids the growth of plants, and it is very strong."
And the Numbered Air Force Commander spake unto the Deputy Commander of MAC, saying,
"It promoteth growth, and it is very powerful."
And the MAC Deputy Commander reported unto the General of MAC, saying,
"Your powerful new policy will help promote the growth of the agency."
And the General looked upon the policy, and saw that it was good.

The last point, in summarizing this organizational paradigm is that systemic distortion is not likely to be seen, critically examined, scrutinized or exposed from within the organizational complex because of the disruptive influence on the organization.

Implications for Aviation Safety

The implications of the paradigm of adaptive avoidance of disorder and systemic distortion of information are potentially broad, indeed. However, I will focus on its implications for accident investigation and on the relative disruption potential with respect to the components of availability[70] (ubiquity, instantaneity, ease of use, and safety) and the related pressures of the technological background.

Accident Investigations and the Avoidance of Disorder

It has become increasingly apparent that accidents and disasters eminating from complex sociotechnical systems often have long incubation periods. [332] Unfortunately, conditions affecting risk potential shape themselves over time in ways that are either not perceived, are effectively argued not to be important or significant, or are simply ignored. It is often only after the shock of a physical disruption to the system, i.e. an accident, that the organizational complex may, or still may not, be prodded into some action that addresses those conditions. But even after an accident, there is less disorder generated in the system if the accident can be attributed to "operator error," unless of course the operators, themselves, have the power to create significant disorder in challenging such conclusions. In fact, statistics show that human error has been well recognized as the dominant cause, with approximately 70% of aviation accidents having been attributed to human error. [333] On this topic, Charles Perrow writes:

> ...the prevailing view in most organizations is that failures are the result of operator errors, rather than errors of engineers or top management. ...The attribution of operator error in the face of system failures is widespread in all systems, especially in high-technology systems. Only where operators are strong and well organized, as are commercial pilots -- in contrast to most industry and the military -- is there significant resistance to this easy view. The attribution of operator error emerges as a residual category -- if no equipment has failed, it must be the operator, since sophisticated designs are [thought to be] inherently more fool-proof than simpler ones. ...OSHA investigators, the National Transportation Safety Board, and many in congressional inquiries also prefer to conclude that operator error is the principal cause. Since human behavior is harder to change than mechanical behavior, it would appear to be a counsel of despair, but it is convenient and also wards off a deeper despair in connection with systems with catastrophic potential. [334]

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70 See Chapter 5.

Diane Vaughan also cautions that the accounts of official investigations must be considered in the context from which they arise, as they are a "product of the politico-socio-historical environment that produced them ...[and they] shape what outsiders perceive as cause." [335]

Further, such focus seems to be systemically entrenched, in that traditional accident investigation techniques proceed in an apodeictic proximal cause-and-effect manner. These techniques have...

> ...largely been confined to, and concentrated on, a search for technical or mechanical failure, together with the routine examination of the statements of the pilot and associated personnel in order to confirm that all regulations and procedures have been obeyed. If any violation of such regulations and procedures are found the cause may be described as 'pilot error'. [336]

Feggetter's proposed methodology to assess human behavior in instances of aircraft accidents provides a much needed deeper look at the 'why?' question of operator error, seeking "an explanation in terms of the causes and mechanisms of failure." [337] But it is still an apodeictic explanation centered around the operator and, as we have discussed earlier, such a framework does not allow adequate penetration into the contextual factors. We are left frustrated, in that it is difficult to "prove" that accidents, in their apparent uniqueness, are the result of contextual factors. Thus, even though the consequences of poor system design, including poor maintenance policy or poor scheduling policy, for example, are borne by the operators who must make the system work on a daily basis, when the operator argues that the system is poorly designed his comments are perceived by everyone else to be self-serving. [338] The operator does not normally influence sufficient disorder-inducing resources to overcome the system's inherent tendency to avoid disorder. The weight and influence carried by management and technical experts swamp out such perceptions, either convincing the operator it is lack of skill or ability on his part, failure to follow procedures or simply stifling their dissent. Thus, information is selectively filtered and distorted regarding such contextual factors as technology, itself.

It is a dilemma of apodeictic analysis, as Vaughan acknowledges with regard to her investigation of the *Challenger* disaster: "We can conclude that the organizational patterns uncovered were correlated with the accident, but no direct evidence exists that allows us to assert that these organizational patterns *caused* the accident." [339] However, she points paradigmatically to the context of the *Challenger* accident. By articulating the organizational contribution to technical failure, she challenges existing assumptions about the ability of regulatory structures (in this case) to control risky technologies, noting paradigmatically that the fundamental structure of inter-organizational relations...

> ...will continue to generate patterned obstacles to social control. ...Clearly, a technical explanation is insufficient to explain the *Challenger* tragedy. The existence of organizational patterns that contribute to failures of foresight increases risk. ...Policy makers and advocates need to take into account the organizational contribution to technical system accidents when defining technical systems as more or less risky... While we cannot make precise recommendations from this research, we can safely conclude that intra- and interorganizational relations are characterized by structurally engendered weaknesses that contribute to technical system accidents. [340]

James Reason, author of the most up-to-date work on human error [341], addresses similar points in his research. He states that:

> Although the errors and violations of those at the immediate human-system interface often feature large in the post-accident investigations, it is evident that these 'front-line' operators are rarely the principal instigators of system breakdown. Their part is often to provide just those local triggering conditions necessary to manifest systemic weaknesses created by fallible decisions made earlier in the organizational and managerial spheres. [342]

In comments referring to the right lessons to be learned from past accidents, including Three Mile Island, Chernobyl, Bhopal, *Challenger*, and Zeebrugge, he identifies two universal and recurrent human failings that institutions exhibit in their reactions to other people's catastrophies: blaming the individual operator(s) and perceiving the situation as unique, requiring only local fixes. More technically, these are referred to as the *fundamental attribution error*, which has been widely studied in social psychology and the *fundamental surprise error*, a term coined by an Israeli social scientist in regard to the Yom Kippur War. Illustrating these concepts with documented reactions to the accidents at TMI, Chernobyl and others, he describes them as follows.

> The *fundamental attribution error* ...refers to a pervasive tendency to blame bad outcomes on an actor's personal inadequacies (i.e., dispositional factors) rather than attribute them to situational factors beyond his or her control.
>
> ...A *fundamental surprise* reveals a profound discrepancy between one's perception of the world and the reality. A major reappraisal is demanded. *Situational surprises*, on the other hand, are localised events requiring the solution of specific problems. ...The natural human tendency is to respond to fundamental surprises as if they were only situational ones. Thus, the *fundamental surprise error* is to avoid any fundamental meaning and to learn the situational lessons from the surface events. [343]

And Reason characterizes the essence of the right lesson and general conclusions to be obtained from TMI, Chernobyl, Bhopal, *Challenger*, and others, by quoting from David Woods' reflection on technology and TMI:

> The TMI accident constituted a fundamental surprise in that it revealed a basic incompatibility between the nuclear industry's view of itself and reality. Prior to TMI the industry could and did think of nuclear power as a purely technical system where all the problems were in the form of some technical area or areas and the solutions to these problems lay in those engineering disciplines. TMI graphically revealed the inadequacy of that view because the failures were in the socio-technical system and not due to pure technical nor pure human factors. [344]

Reason argues that it is not operator error, but what he refers to as "latent failures" or "resident pathogens" imbedded in the system, that "constitute the primary residual risk to complex, highly-defended technological systems." [345]

Availability and Disorder

How do we explain the inherent tendency of organizational complexes to avoid the pursuit of penetrating and incisive insight into the broader concerns of safety? How do we explain their lack of perseverance in the prosecution of sustained and steadfast action that would continue to improve the risk situation rather than erode it? It was noted in our discussion on the paradigm of technology[71] that the elements of availability that are most directly experienced, e.g. ubiquitous and instantaneous availability of a commodity and, to a lesser extent, ease of use, all three of which I will refer to subsequently as the dominant elements of availability, receive more attention than safety, which is essentially experienced by the absence of a particular phenomena called accidents. The dominant elements are directly, physically and continually experienced through consumption and thus represent a persistent and interminable source of disorder-inducing forces on organizational complexes, via the market place if no where else. Continual adaptive adjustments are made by organizational complexes to resolve these disorders. The technological background expectations, which emphasize productive and efficient use of resources, performance of tasks in an orderly manner to achieve objectives, and so forth, are geared to focus organizational efforts on the most commonly experienced disorders, those caused by the dominant elements of availability. These background expectations help the organization contain and resolve disorder. Individuals, as it was noted, learn and meet these expectations, because to do otherwise causes internal disorder which the system must accommodate, usually at the expense of the individual.

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71 See Chapter 5.

Safety, of course, has its own sources of disorder. Accidents are a physical source of disorder for an organizational complex, often of staggering proportions (e.g. *Challenger* and the NASA mission/regulatory complex). And a publically perceived record of accidents can cause significant disorder for complexes through the market place. During the rash of DC-10 accidents in the 1970's, did you ever ask what type of plane was scheduled for your route and select another route or airline if it was a DC-10? I did! Now that considerable time has lapsed since those accidents, do you still concern yourself with which airplane is scheduled? I don't either. The consumer perception of a device as unsafe, like the DC-10 or the Ford Pinto for example, or the air travel system in time of war, can cause organizational complexes to make significant structural adaptations to the market-induced disorder -- e.g. changes in reporting relationships, decision processes, product-line changes, increased security, reduction of fares, etc. Sometimes it even takes several accidents to build that perception and market place reaction before organizational complexes change. And for some organizations, the military for example, the disruptive effects of accidents can be so effectively damped out that virtually no structural adaptations are required to adjust to the disorder. Disorders are contained -- boxed in locally in a way that minimizes disruptive influence on organizational policy and practices. We'll see examples of that later on.

But the *absence* of physically caused disorder is problematic. It is certainly what we desire -- no one wants to experience accidents -- but, the absence of physically induced disorder results in the dissipation of energy and resources that were thought to be needed to achieve and maintain adequate safety (let alone improve it) on a continual basis. This is what happened to the emergency response system for environmental protection promised by the oil industry for the pipeline terminating at Valdez, Alaska, and the management of supertanker traffic. The capabilities to respond to accidents, whether originally adequate or not, slowly eroded over time. It took the Exxon spill to shock the system into a readjustment of resources. Of course the disorder was enormous -- organizationally, economically, environmentally, and publically. In the absence of physical disorders related to safety, resources that might be targeted for safety tend to flow to activities that resolve the disorders that continue to be experienced, those related to the dominant elements of availability. That is obviously why we have advocate institutions and regulatory agencies such as OSHA, UL, EPA, and the FAA. They are the sources of compliance and/or deterance disorders through their activities of discovery, monitoring, investigation, and sanctioning. They are *supposed to* produce disorders that the organizational complex must adapt to, hopefully in the appropriate way. But their effectiveness is often in question and we still see the same phenomena -- that of safety dropping in priority over time, relative to the dominant elements of availability.

Unfortunately, the organizational paradigm of disorder avoidance and information distortion is present throughout the complex, and a regulatory institution, itself, is part of the same organizational complex as the regulated industry. We have already noted Perrow's comments on the close link of the FAA with the aviation industry that it regulates. Diane Vaughan does a thorough examination of the organizational bases of the ineffectiveness of NASA's three regulatory units and it will help us explicate our paradigm by seeing that social control agents are not exempt from the pattern. The NASA regulatory structure at the time of *Challenger* consisted of two intraorganziational units (the Safety, Reliability, and Quality Assurance Program; and the Space Shuttle Crew Safety Panel) that existed at the inception of the shuttle program; and a third independent external regulatory body reporting to Congress (the Aerospace Safety Advisory Panel). The third, incidently, is another example of a structural change in the agency/regulatory complex that resulted from a physically induced disorder, namely the 1967 Apollo launch-pad fire that killed three astronauts.

Now, it is important to emphasize that all of these units have a strong moral commitment to safety; it is their only mission. How could there be such a failure? NASA created its regulatory structure to ensure *both* safety and innovation by separating oversight responsibilities for these two goals. The shaping of policies and technological developments to encourage innovation was accomplished through a system of advisory committees staffed with respected leaders from the aerospace industry, research institutes, and universities. To assure safety while maintaining necessary secrecy, the two internal units mentioned above were created with the sole responsibility...

> ...to assure safety through intensive scrutiny of both technical design and program management. These two internal safety units were created with the expectation that NASA personnel, informed about its technology, management systems, personnel, and with access to day-to-day activities, were capable of the close monitoring essential to safety. Moreover, these internal units were physically separate from the activities they were to regulate, so they were expected to bring to their task the objectivity necessary for independent review. [346]

With the disorder caused by the Apollo accident, Congress supplemented NASA's own advisory committee structure with the third unit mentioned above, an advisory committee soley responsible for safety surveillance.

> The creation of this panel was an explicit attempt by Congress to balance NASA's internal safety system with an independent external regulatory body composed of aerospace experts. Legislative action was guided by the notion that the combination of internal and external regulatory bodies would provide the surveillance essential for preventing future accidents. [347]

We are talking about a very elaborate safety structure for NASA, with many hundreds of people devoted to the safety mission. But, Vaughan's research has shown that there are constraints on the efficacy of social control of organizations that have their roots in the inherent properties of organizational complexes. These have to do with how interorganizational relations constrain intended social control. Regulatory relationships are characterized by two paradoxical qualities, in that regulatory organizations and the organizations they regulate have the capacity to be autonomous and interdependent simultaneously, both of which inhibit control efforts. Autonomy relates to the fact that social control agents and the regulated organizations exist as separate, independent entitites. As with any complex of organizations,

> ...physical structure, reinforced by norms and laws protecting privacy, insulates them from other organizations in the environment. The nature of transactions further protects them from outsiders by releasing only selected bits of information in complex and difficult-to-monitor forms. Thus, although organizations engage in exchange with others, they retain elements of autonomy that mask organizational behavior. ...Autonomous structures in their own right, regulators are mandated to oversee the behavior of other organizations. But the autonomy of regulated organizations obstructs the gathering and interpretation of information necessary for discovery, monitoring, and investigation. Regulators attempt to penetrate organizational boundaries by periodic site visits and/or by requiring the regulated organization to furnish information to them. [But] these strategies allow regulators to examine only limited aspects of organizational life... [348]

Given its size and complexity, its numerous daily transactions, its specialized lexicon, and its continually changing technology, it is easy for the target organization to become a fog generator. And information is also easily distorted through the mutual dependence that is required for the regulator organization to do its job.

> Attempting to surmount these obstacles, regulators tend to become dependent on the regulated organization to aid them in gathering and interpreting information. While certainly the potential exists for a productive relationship, informational dependencies also can undermine social control in subtle ways. First, regulators' definitions of what is a problem and the relative seriousness of problems are shaped by their informants. Second, informational dependencies tend to generate continuing relationships that make regulators vulnerable to cooptation. Regulators may take the point of view of the regulated because they develop sympathy and affinity for them, compromising the ability both to identify and report violations. Finally, the situation is ripe for intentional distortion and obfuscation by the regulated, for informational dependencies prevent regulators from detecting falsification. [349]

Vaughan goes on to note that, whether the interdependence be symbiotic or competitive, its major impact is on the ability of regulators to threaten or impose meaningful sanctions. Symbiotic interdependence relates to resources that are exchanged, one organization's output functioning as the input of the other. Thus, there is a tendency of the organizations to rise or fall together, when harm or good fortune befalls one or the other.

In a competitive sense, resources of each organization can be used in ways that interfere with the goals of the other. For example, the regulator can impose costs or threaten the smooth running of operations of the regulated organization; but the regulated organization possesses resources such as wealth, influence, and information that can interfere with the successful completion of tasks necessary for social control. The natural tendency, however, is for both organizations to avoid significant disorders and disruption of resources. Consequently, Vaughan writes, "both regulator and regulated tend to avoid costly adversarial strategies to impose and thwart punitive sanctions; instead, bargaining becomes institutionalized, as negotiation demands fewer resources from both. Hence, sanctions often are mitigated as a result of the power-mediating efforts of both parties." [350]

Although compromise can still be considered an enforcement pattern itself, interdependence dissipates the ability of regulators to threaten or impose meaningful sanctions, and this was exacerbated further by the internal reporting structure and control of resources NASA had over the safety units. The outcome was that there was no credible threat of disorder for a consequence to safety violations by NASA or its contractors. NASA, its contractors, and the safety regulatory units all certainly had the common goal to prevent accidents. But, efficiency and production goals had priority over safety. The potential disorder created in the interest of production was greater than the potential disorder in favor of safety, for production addresses the dominant elements of availability.

Systemic Distortion of Information and the Erosion of Safety

Systemic distortion of information we described earlier as a subtle emergent property that characterizes organizational complexes. Through the patterned tendency to adaptively avoid disorder, pressure exists to collect and interprete information that is biased toward favorable perceptions of the organization and its behavior. So, the longer an organization or complex goes without a physical disorder related to safety while routinely addressing recurrent disorders due to the dominant elements of availability, the more favorable it perceives its behavior in regards to safety. In fact, it begins to perceive excesses over and above the margin originally thought necessary and it becomes easier to make decisions which divert resources to other areas where disorder continues to be experienced. Through time, more and more distortion takes place and the favorable impression becomes more entrenched even as safety margin is eroded by diversion of resources, complacency, etc. This means that the longer the absence of some major disorder, like the physical disruption caused by an accident, the larger the disorder it will take to readjust the perception and overcome the cumulative distortion. In systems where accidents are rare, disorders caused by operators complaining of safety conditions or irregularities, for example, are generally not sufficient to counter the disorder that might be generated in actually dealing with the safety issues that are raised. Less disorder for the organization results by simply dealing with the operator instead, through rewards and sanctions that selectively favor positive information for the organization.

The credit for the general idea presented here is due to David Bella [351], who, with his colleague Peter Klingeman, proposed it for consideration in the context of failures in technological systems with environmental damage to natural resources; where current risk assessment methodology does not give consideration to organizational factors. It has its foundation in Bella's paradigm of organizational complexes discussed in this chapter. Bella and Klingeman reason that the probability of rare and catastrophic technological failures tends to increase over time in ways that are hidden to most risk assessments, which are rarely sensitive to organizational changes. Understanding organizational complexes as adaptive systems adjusting through countless individual decisions to experienced disorders, explains the tendency for them to settle into those arrangements that accommodate recurring disorders so as to prevent them from growing and spreading. In the context of technological failures, this concept can be seen as follows.

> The probability of any technological failure depends upon many human factors, including the training, skill and morale of operators, the effectiveness of maintenance programs, quality control inspections, and in general, the effort and attention given to possible failure modes. These human factors in turn depend upon the organizational structure, the information and resource network that it sustains, and the activities that these support. The organizational structure in turn reflects the history of disorders that have been experienced within the organizational system. Technological failures are disorders that promote adaptive changes that tend to correct the failiures or to cover them up. Rare technological failures, however, by definition are infrequently experienced. Catastrophic failures which

> should be exceedingly rare are almost never experienced. This is fortunate but, ironically, it is also dangerous. Catastrophic technological failures only directly influence the adaptive history of an organization after it is too late. Over time, an organization adapts in response to the more frequent disorders that its members actually experience. Loss of funding is an actual or potential disorder that is pervasively experienced. To a large degree, an organizational system adapts to accommodate such disorders. Through such adaptation, perceptions are shaped and resources are allocated to certain activities and not others. Disorders and failures not experienced become less relevant to the activities of the organization. Such adaptive changes occur through the decisions of many people who are working to resolve the problems that actually confront each of them. [352]

A reading of Vaughan's organizational analysis of the *Challenger* disaster will give you a good illustration of just how this can happen. The adaptive changes over time included not only the diversion of resources away from safety, an obsession with production goals, and selective filtering of information regarding the severity of the long known O-ring problem; but, the actual elimination of one of the safety regulatory units when its principal proponent and driving force retired. They were not experiencing sufficient safety related disorder to justify (to themselves) keeping the unit operating. [353]

> As the system settles into arrangements to accommodate those disorders actually experienced, potential catastrophic failures which have not been experienced are less able to draw in resources, effort, and attention from the system. In effect, catastrophic possibilities become neglected not through the laziness or incompetence of particular individuals, but rather through a history of countless decisions by people seeking to direct resources, efforts and attention (all of which are limited) to the many and diverse problems that one or another has actually encountered. Those who have been most successful at resolving recurring disorders may in effect be most responsible for the neglect of catastrophic possibilities! As the adapting system directs less resources, efforts and attention toward catastrophic possibilities, the probabilities of such catastrophic possibilities increase. But probabilities are not directly experienced. Only events are experienced. Thus, probabilities that increase have little or no influence upon the adaptive change of organizations unless they can appear as an event that provokes decisions and organizational change. Until such events occur, one must conclude the following: Through adaptive organizational change, the probabilities of rare and catastophic failures tend to increase while, at the same time, the perception of such failures becomes more remote in the minds of those within the organization. The gap between actual risk and perceived risk widens. When a society comes to depend upon organizations and their experts for the assessment and management of technological risks, the stage is set for catastrophic surprise. [354]

The organizational context even works against those whose focus is on the "human-in-the-loop." In Perrow's discussion of the organizational context of human factors engineering, he points out that human factors engineers tend to have a perspective restricted to the "isolated human, subject to biological limitations," since their education has more of an engineering psychology element than a sociological or organizational perspective. But beyond that, with the important perspective of the operator that human factors engineers do have and the contributions they can make, they have been relatively ineffective organizationally in influencing systems design.

We see the same paradigm here. Human factors professionals generally do not have the organizational stature or control the kind of resources necessary to generate sufficient disorders in the design process to adequately influence system design. They are not numerous, which means fewer links to the organization's environment. They control fewer resources, in particular discretionary resources, than design engineers. The qualitative nature of their specialty, much of which comes from common sense professional judgment, means they are easily subverted by the more quantitative "hard engineering" disciplines (recall, technological expectations). For example, industrial engineering graduates, the discipline most commonly recognized as the home of human factors engineering[72], are not even classified as "true engineers" by the Boeing Company for pay curve, promotion and job status. [355] Thus, when trying to influence or confront design engineers or management regarding human factors considerations, they are disadvantaged and constrained to emphasize those findings or skills that use quantitative data. Finally, their constituents are seen to be the operators, whereas design engineers are seen to have top management as their constituency. And we get back to the point that arguments in favor of the operators, such as the ease of use component of availability, create less disorder than design efficiency and the other two dominant elements of availability. This is because the prevalent view in most organizations, as we have mentioned before, is that failures are not the result of engineering or top management, but operator behavior. [356]

We are now ready to examine a specific accident and its formal investigation in considerable detail. In the previous four chapters we have developed, justified, and cumulatively integrated four paradigms; and we have contemplated their implications for aviation safety. The MAC 40641 accident is not intended to represent "empirical evidence" of the paradigms. Recall that to attempt to prove or disprove paradigms is fruitless. Paradigmatic explanations are intended to inform and illuminate us in a way that enhances our understanding of phenomena. The MAC accident is an illustration of that. It is a concrete example that illustrates much of the patterns we have thus far developed. The MAC accident is a paradigm of the context of aviation safety.

72 Many of those who work in the human factors arena, however, are psychologists by education, according to the Human Factors Society directory.

Chapter 8

Explaining the MAC 40641 Accident

In this Chapter and the next we will examine the MAC Flight 40641 accident in considerable detail. At the outset I wish to make it emphatically clear that no pretense is intended for this inquiry to represent an examination of current flight safety in the United States Air Force. Such a study would be far beyond the scope of this work. Nor is there any intention to discredit any individual or organization. However, I intend to draw out the entire story and it is not without an unflattering side. This should bring no embarrassment to anyone as the purpose here is to learn something.

In this inquiry I will draw upon, quote and cite many sources that are publicly available in order to draw explanatory distinctions, enhance understanding and illustrate direct and contextual aspects of this mishap. The fact that this accident is 16 years old at the time of this writing would make any direct inference from this accident alone to current situations in the same organization(s) dubious with out further investigation; and that is beyond the intent of my purpose here.

There are many possible approaches to examining past events, the circumstances surrounding them, and the interpretation, conclusions and lessons to be drawn from them. Graham Allison's *Essence of Decision* [357] illustrates the insight that can be gained and the lessons learned from examining a concrete event, the Cuban Missle Crisis in his case, from multiple frameworks. That is what I wish to do with these next two chapters. We have developed a fairly in depth description of the notions of apodeictic and paradeictic explanations in Chapter 2, and the four paradigms that bear on flight safety in the previous four Chapters. We are now in a position to understand the type of insight that can be gained from each explanatory approach in its isolation and, through the examination of a specific concrete accident event, see how we can acquire quite different views of flight safety depending on our cognitive framework.

The intention of these two chapters, and the use of the C-141 accident, is to contrast the kind of insight gained through an apodeictic explanation that is characteristic of traditional thinking about flight safety and accident investigation, with that gained through a paradeictic (or paradigmatic) explanation, where I will point up some of the patterns that are paradigmatic in the sense of the paradigms that were developed in the previous four chapters. Again, let me point out that my purpose is to broaden the framework of aviation safety in a way that enlightens us regarding contextual aspects of the problem. It should be kept in mind throughout that paradeictic explanation does not replace traditional apodeictic explanation; it complements it.

Finally, an ancillary objective of this work is to fully document all available information relevant to this specific accident. Thus, the discussions below will be penetrating, containing considerable detail from original sources. Discussion, summaries and reflections will be presented throughout; but in my view, the impact and full understanding of this accident from the two approaches cannot really be appreciated with out "seeing" it for yourself. To merely present a "boiled down" summary of this accident would leave the reader, I am afraid, in a state of unsatisfied bewilderment, wanting for more of a view from the inside.

Nothing takes the place of direct and patient examination of original source material. You will be guided into much of the official interpretation and much of the documented stories as told in the testimony of sworn witnesses and the interviews of other crew members of the Military Airlift Command. I will try to fill in some of the cultural context, where I believe it advances understanding, from my own experience as a crew member in MAC.

Understanding the USAF Accident Investigation Process

For proper interpretation, it is important to understand the legal and administrative context under which the following analysis is examined. [358] The Air Force considers three categories and four classes of "aircraft mishaps." The categories (Flight Mishaps; Flight-Related Mishaps; and Aircraft Involved Mishaps) relate to whether or not there is reportable damage to an aircraft and the intention for flight; with "Flight Mishap" being the category that includes airborne accidents such as the 40641 mishap. The four classes (Class A, B, C, and D) relate to the severity of damage; with Class A being the most severe, defined by the following criteria: (1) Total cost of $1,000,000 or more, or; (2) A fatality or permanent total injury, or; (3) Destruction of or damage beyond economical repair to an Air Force aircraft. Obviously, MAC 40641 met all of these requirements and therefore is considered a "Class A Flight Mishap," in Air Force lexicon.

Dual Investigations and the Safety Privilege

Aircraft Class A mishaps require two investigations: A "Safety Investigation" for safety improvement purposes; and an "Aircraft Accident Investigation" for legal liability purposes. The purpose of the dual investigation system is to separate information that would be useful to accident prevention from that which might be used in court or for disciplinary and administrative action purposes. The "Safety Investigation" is convened under the authority of the MAJCOM[73] commander (or Numbered Air Force (NAF) commander if delegated) in which the accident occurred; the safety board's investigation is conducted under Air Force Regulation (AFR) 127-4. The "Aircraft Accident Investigation," also referred to as the "Collateral Investigation," is convened under the authority of the same MAJCOM commander, or NAF commander if delegated, that convened the AFR 127-4 investigation; but, it constitutes an entirely separate investigation whose board, or investigating officer, is different from that of the Safety Investigation. The Accident Investigation operates under AFR 110-14. The reports from these investigations are referred to as the "127-4 Safety Investigation Report, Parts I and II" and the "110-14 Collateral Aircraft Accident Investigation Report."

Safety Investigation: AFR 127-4

The safety investigation has priority over the accident investigation. Its purpose is to find causes and prevent recurrences. The formal report from this investigation contains two parts.

Part I (Facts): Part I of the formal report is intended to be releasable under the Freedom of Information Act (FOIA), (5 USC 552), and, as such, is not marked for special handling or identified as "FOR OFFICIAL USE ONLY." Its purpose is to: a. Show needed information for use in mishap prevention; b. Segregate factual

73 MAJor COMmand, e.g. SAC (Strategic Air Command), TAC (Tactical Air Command), MAC (Military Airlift Command), etc.

information which may be disclosed outside the Air Force; c. Aid in retention of privileged information and protect privacy of medical information; and d. Serve as generally nonprivileged material given to the AFR 110-14 board (and others requesting safety board report information through the releasing authority, HQ AFISC -- Air Force Inspection and Safety Center).

It is the policy of the U.S. Air Force that the public be informed of Air Force action and activities, both favorable and unfavorable; however, the release of information is limited to facts, avoiding any conclusions and excluding or even suggesting admitted responsibility on the part of any person, recommended corrective actions, statements or opinions of any witnesses, quotations or paraphrases from any limited-use reports, and several other such categories of information.

Part II (Privileged Data): Part II of the formal report is a limited-use report, not releasable in whole or in part to persons or agencies outside the Air Force and with severely restricted distribution and use within the Air Force. The Air Force exercises a claim of executive privilege for this information and it has withstood the challenge of several court cases and appeals. Part II and all related documents have the sole stated purpose of preventing safety mishaps. The promise of confidentiality is given to *all* witnesses called by the safety board, and all contractors and others who contribute in the investigation. The purpose is to obtain completely candid information without the witness fearing retribution for culpability, through litigation, disciplinary action, adverse administrative actions, flying evaluation boards and so forth.

The Air Force believes that this system is better than that used by the NTSB; in the opinion of the safety investigation office, experience has shown through the years that they get more candid comments because of the privileged nature of this part of the report and the strict promise of confidentiality to any persons involved. The privilege extends to any portions of mishap safety investigation reflecting Air Force deliberations, conclusions, or recommendations as to policies that should be pursued. Thus, the public does not have the opportunity to learn directly what the Air Force learns from such investigations.

Specifically contained in Part II are:

Tab T: Considered the most important part, containing opinions of the board, including their findings and determination of cause, and recommendations for flight safety policy, procedures, etc. Also protected under this part are transcripts or accounts of *intra*-cockpit communications. (Air-ground radio communications are considered public information and thus are included with Part I.)

Tab U: Statements and testimony of witnesses and persons involved. (List of witnesses *only* is given to AFR 110-14 accident investigation board.)

Tab V: Statements of persons mentioned in findings. This statement is in addition to any other statements or testimony provided by the person during the course of the investigation. Rebuttals would be included in this section.

Tab W: Technical and engineering evaluations of materials (Contractors). Why? If contractor is at fault or design defect is involved, the Air Force wants them to disclose and correct. Confidentiality and privilege protects admissions of liability.

Tab X: Not often used (mainly for missles).

Tab Y: Life science section. This section would include any medical information regarding participants in the accident. It would also include any human factors analysis.

Tab Z: Record of the board's proceedings and investigation.

Aircraft Accident Investigation: AFR 110-14

The purpose of this investigation, unlike the aircraft safety mishap investigation, is to obtain and preserve available evidence for claims, litigation, disciplinary and administrative actions, and for all other purposes. It is not intended to determine cause. The accident report is not privileged and is releasable to anyone upon request.

Evidence provided to the Accident Investigation Board by the Safety Board includes essentially Part I of the AFR 127-4 report and a list of witnesses who testified or provided statements to the Safety Board. Evidence *not* releasable to this investigation includes witness statements or testimony given to the Safety Board (witnesses cannot be asked to tell the AFR 110-14 board what he or she said to the safety investigators -- the AFR 110-14 board has to develop its own testimony/statement, which is done with witnesses under oath after being advised of their constitutional rights, potentially in the presence of legal counsel). Also, specifically not releasable to the 110-14 investigators are safety investigation proceedings, findings, conclusions, opinions, or recommendations; life sciences report; or internal cockpit voice recordings.

MAC 40641

In the examination of this accident I have drawn upon all available sources of information, which are described as I introduce them below. In addition to existing publicly available information, I have pursued other information regarding this accident from Air Force authorities, including Part II of the Safety Investigation Report.

Shortly after the accident, Senator Warren G. Magnuson of the State of Washington requested a full report from the Air Force on the accident or legal justification if it did not plan to make publicly available a full report on reasons for the C-141 crash. In a letter to John L. McLucas, Secretary of the Air Force at the time of the mishap, Magnuson wrote:

> I would appreciate having an early and full report from you as to what information the Air Force does not intend to make public about its investigation of the crash and when it expects to release that information. If the Air Force does not intend to make its entire report public, then please advise me as to the legal justification the Air Force has for not doing so. [359]

The letter was sent in response to a news bureau's query on whether the Air Force could withhold details under provisions of the Freedom of Information Act. The Air Force's Office of Legislative Liaison indicated that it could possibly make a partial report available, a "statement of circumstances" surrounding the mission and eventual crash, but that the safety investigation report regarding the cause would not be releasable. They cited the argument discussed above regarding the guarantee of complete confidentiality for witnesses appearing before the board.

> Confidentiality is given in an effort to persuade all individuals involved to make full and accurate disclosure of all relevant knowledge which they possess even though disclosure of some of the information may be embarrassing or constitute self-incrimination. They are assured that statements made, and any conclusions which might be based on the investigation, will be used for accident-prevention purposes only, and that they will not be released outside safety channels. [360]

A report was eventually delivered and released by Senator Magnuson's office.[74] Portions of this report were cited in a news article. [361]

The 40641 accident is now 16 years old and it was a non-sensitive routine flight under the control of the FAA in commercial air space. For these reasons, and for the purpose of scholarly research, I attempted to obtain Part II of the safety report

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74 Senator Magnuson is now deceased.

under the Freedom of Information Act with the help of Senator Brock Adams of the State of Washington, who wrote a letter to the current Secretary of the Air Force on my behalf requesting the utmost consideration for my request. [362] The request was considered by the Air Force and denied. [363] Through subsequent discussions with Lt Col Michael Torgeson, Legal Advisor to the Directorate of Aerospace Safety, HQ AFISC, who drafted the letter of denial for the Chief of Staff, I learned that no time limit exists on the confidentiality of the information. I indicated that my need was not to know *who* made what statements or conclusions, and thus the report could be sanitized in that respect to protect confidentiality. Col Torgeson explained that, regardless of the potential sensitivity (or lack of it) with respect to this information, the Air Force does not wish to set a precedent by releasing Part II of any mishap safety report under any circumstances. In their view, protecting limited-use reports and the safety privilege requires the consistent demonstration of intent not to release them outside the Air Force. The legal lid on Part II of the Safety Investigation Report is very tight, indeed.

The AFR 110-14 report is a publicly releasable report. Unfortunately, at the time of the 40641 accident, I have been told, the retention period for the AFR 110-14 report was somewhat shorter than it is currently and the report appears to be no longer in existence. Col Torgeson attempted to recover a copy on my behalf; but after he contacted organizations within Air Force that might have a copy of the 110-14, he was unable to locate one.

As luck would have it, I discovered seven folders of material on the McChord accident in the archives of Senator Magnuson's papers at the University of Washington. [364] These contained a complete copy of the 110-14 Collateral Investigation Report, which includes the sworn testimony and statements from over 50 witnesses.

AFR 127-4 Investigation Board

Listed here for completeness and to point out the organizational representation involved in this investigation, is the make-up of the AFR 127-4 investigating board. The ultimate responsibility for the investigation is the commander of the Military Airlift Command, Gen Paul K. Carlton, headquartered at Scott AFB, IL. Gen Carlton appointed an immediate subordinate, Maj Gen Ralph S. Saunders, Commander of the Aerospace Rescue and Recovery Service, to head the investigation board. The ARRS, also headquartered at Scott AFB, is part of MAC. The 62nd Military Airlift Wing (MAW) at McChord is under the 22nd Air Force, commanded by Maj Gen John Gonge.[75]

Table 8.1 MAC 40641 Safety Investigation Board.

Maj Gen Ralph S. Saunders	President of Safety Investigation Board, ARRS/CC (MAC)
Maj Courtney W. Wells	Investigating Officer, 63 MAW/SE (MAC)
Maj Charles S. Gorton	Pilot Member, 22AF/DOV (MAC)
Capt Robert A. Lane	Maintenance Member, 22AF/LGM (MAC)
Capt Charles G. Hubbell	Medical Member, 62 MAW (MAC)
Capt Thomas C. Jones*	Recorder, 62 MAW (MAC)
Maj Jack N. Dole*	MAC Representative, HQ MAC/IGFF (MAC)
Col David A. Shinn	62 MAW Representative, Resource Manager (MAC)
Mr James R. Banks, GS-15	AFCS Asst DCS/FF, AFCS (MAC)
Mr Ruldolf Kapustin*, GS-14	Senior Air Safety Investigator, NTSB Representative, Wash DC
Mr John P. Amatetti*	FAA Representative, Wash DC
Mr Donald C Legge*	FAA Representative, Wash DC
Lt Col William M. Dyer*	MAC Surgeon Observer (COMAC directed), USAF Clinic/CC McChord AFB

* Non-voting members

The board's convening orders were dated March 26, 1975. The board members convened at McChord AFB until April 4, 1975, at which point it was disbanded temporarily until weather permitted a thorough examination of the crash site and recovery of the aircraft instruments and flight data recorder. The investigation of the accident site resumed June 2, 1975, under the direction of the board with specific objectives for recovering the remaining crash victims and specific equipment. On

75 Reference to names and duties are current at the time of the accident, unless otherwise stated. For simplicity, I will use present tense throughout most of my discussion.

June 17, 1975, Gen Saunders announced that all of the board's objectives, including recovery of the remains of the 16 victims and recovery of the flight data recorder, had been met and the investigation was complete.

Safety Investigation Factual Information: AFR 127-4 Part I

Part I of the Safety Investigation (AFR 127-4) is the primary source of the analysis presented below. [365] It is a 150+ page document that contains all relevant factual information, including flight orders, mission itinerary, flight path charts, maintenance records, navigational equipment evaluations, NTSB analysis of the flight data recorder, transcripts of radio communications, and analyses of the mission history, aircrew qualifications and status, aircraft performance, weather conditions, the crash and wreckage, and the FAA air traffic control operation at the time of the accident. The information that is provided is thorough and exhaustive.

Obviously we will not be able to compare the conclusions we might draw from this analysis with those of the investigation board. We also do not have access to specific statements from witnesses (Part II, privileged information), nor do we know who all was interviewed by the board. However, these are not of major concern for our purposes here. The only persons alive who were directly involved with the accident were two air traffic controllers. Where their perceptions and opinions had a clarifying impact on the analysis of the facts, it was included in this factual section of the report. The Collateral Investigation provided some clarification on a few particular facts; this was incorporated where appropriate but the analysis is primarily the original source summary of the Safety Board. In this accident there is not much ambiguity in the "facts;" the facts basically speak for themselves and the conclusion is apodeictically apparent.

Overview of MAC 40641 Mission

Mission Route and Itinerary

This was an industrial funded cargo airlift mission, PJN 655, operating to Clark AB, P.I., set up by HQ 22AF with the following itinerary:

Table 8.2 MAC 40641 Mission Itinerary.

Station	Arrival	Departure
McChord AFB, WA		17 Mar/1700z
Tinker AFB, OK	17 Mar/2015z	17 Mar/2330z
Hickam AFB, HI	18 Mar/0840z	18 Mar/2355z
Andersen AB, Guam	19 Mar/0845z	19 Mar/1200z
Clark AB, PI	19 Mar/1545z	20 Mar/1600z
Yokota AB, Japan	20 Mar/2000z	20 Mar/2315z
McChord AFB, WA	21 Mar/0905z	

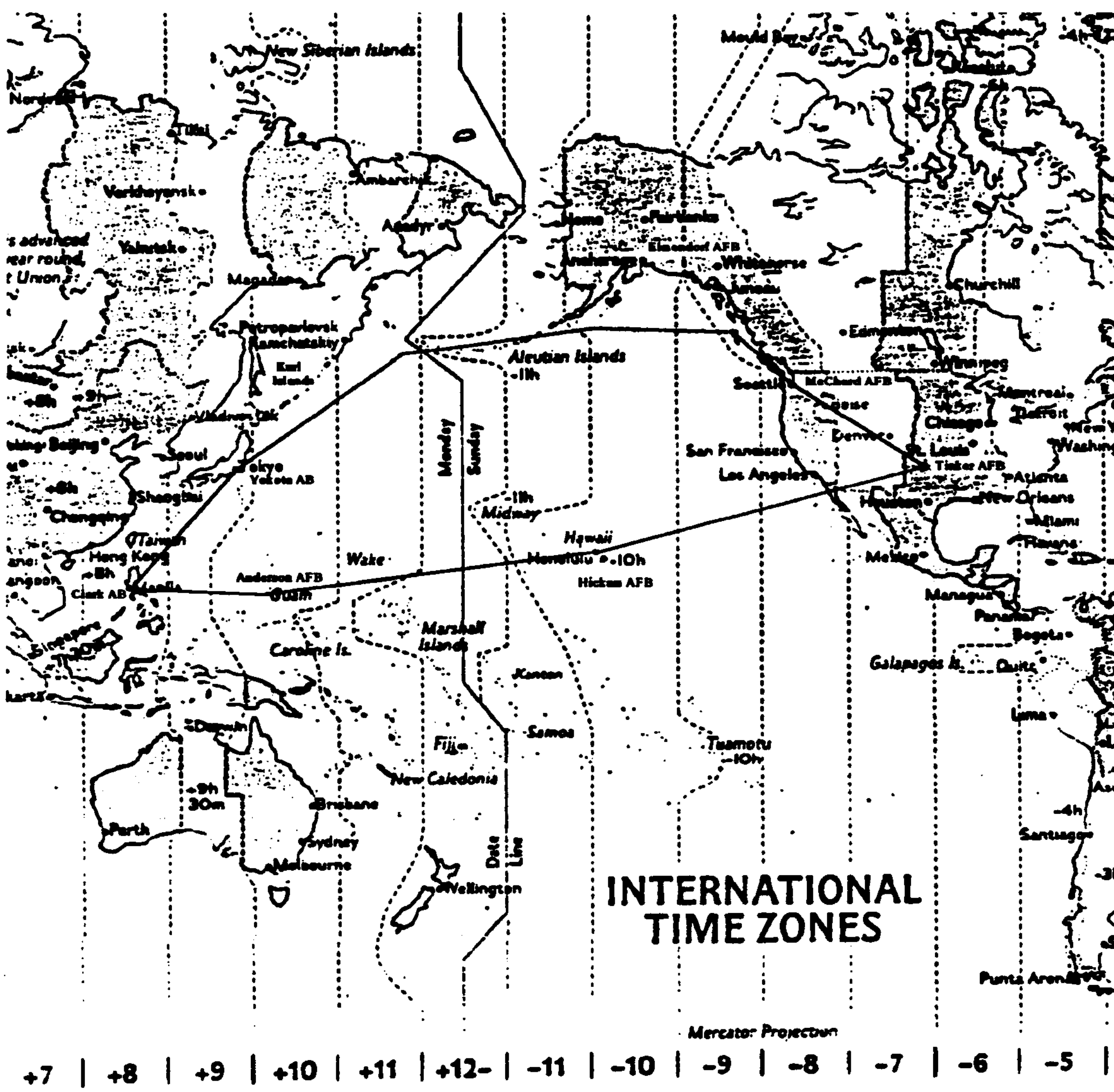

Figure 8.1 MAC 40641 Mission Route.

Aircrew Complement and Scheduling

Aircrew Complement

Military Airlift Command regulations specify that personnel assigned to airlift crews will be qualified, current, and certified in accordance with applicable training directives. [366] Military Airlift Command has two types of crew complements which reflect time limitations on the length of the crew duty day. The *basic airlift crew* is the minimum crew required for any flight. An *augmented airlift crew* is a basic crew supplemented by qualified crew members to permit in-flight rest periods. Crew complement is dependent upon the aircraft type and mission. For the C-141, crew complement directives are described below.

For a C-141 mission a minimum basic crew consists of the following members: a. Aircraft commander/pilot; b. Copilot, or higher; c. Navigator (required on Category I routes which are those where radio aids to navigation, excluding LORAN, aircraft radar and DME are inadequate to determine position accurately once each hour; the 40641 mission involved several Category I legs); d. Flight engineers -- two are required, one of whom may be a second flight engineer; e. Loadmaster. An augmented crew consists of an additional pilot (first pilot or higher) for a total of three pilots, and an additional navigator for a total of two navigators; also, missions requiring the use of an augmented crew which transports *any* number of passengers require two (airlift qualified) loadmasters.

Table 8.3 MAC 40641 Crew Members.

Name and Grade	Age	Qualification	Assigned Duty
Earl R. Evans, 1Lt	27	Aircraft Commander	AC
Frank A. Eve, Capt	27	Aircraft Commander	Copilot
Harold D. Arensman, 2Lt	25	Copilot	Copilot
Richard B. Thornton, Lt Col	40	Navigator	Navigator
Stanley Y. Lee, 1Lt	25	Navigator	Navigator
Ralph W. Burns, Lt Col	42	Flight Examiner Navigator	FEN
Robert J. McGarry, MSgt	37	Instructor Flight Engineer	Flight Engineer
James R. Campton, TSgt	45	Flight Engineer	Flight Engineer
Peter J. Arnold, SSgt	25	Instructor Loadmaster	Loadmaster
Robert D. Gaskin, A/1C	21	Loadmaster, Non-qualified	Loadmaster

Crew Duty Day

A "crew duty day" begins one hour after the crew is alerted for the first leg of a flight and ends when the aircraft "blocks in" on its last leg. The basic crew can be scheduled for a 16 hour crew duty day, which may be extended for up to an additional 2 hours at the discretion of the aircraft commander, depending on mission progression. An augmented crew can be scheduled for a 24 hour crew duty day. Augmented crews are authorized only when one of the following criteria is met: a. At least two flights of four hours each; b. At least one flight of six hours; c. Maximum of four intermediate stops. Air Force regulations state that normally, augmented airlift aircrews will not be used.

Crew Rest

Home station predeparture crew rest for crew members departing on missions with scheduled time away from home station exceeding a basic crew duty day will be provided a crew rest period beginning 24 hours before reporting for a mission. During the first 12 hours of this period, a crew member may accomplish limited nonflying duties. The second 12-hour period is inviolate; no duties may be performed. Infringement of the inviolate crew rest period will effect the start of another 12-hour inviolate crew rest period. When a mission departure time is established, crew members will be notified of a specific time to start predeparture crew rest. Notification must be prior to actual start of crew rest and will be provided in sufficient time to allow the crew members to restructure their schedule of work and rest so as to report for the mission in an optimum physical state.

En route crew rest is established in the following way. Normal ground time between arrival and departure is 15 hours and 15 minutes and starts when the aircraft blocks in. This period will provide the crew the minimum of eight hours uninterrupted rest, plus time for transportation, postflight clearing (maintenance debrief, airlift command post (ACP), customs, etc.), meals, and the normal two-hour and 15 minute predeparture reporting time. MAC Air Force commanders should establish ground times in excess of 15 hours at designated en route stations to provide aircrews, flying several consecutive days away from home station, the opportunity to overcome the cumulative effects of fatigue. The aircraft commander is authorized to modify normal ground time when: a. It is in the interest of safety; b. The mission is behind schedule. He may request less than 15 hours ground time prior to beginning crew rest. The crew will not report for a flight until at least 12 hours have elapsed since termination of the previous crew duty period.[76] ACP will not request the aircraft commander to accept less than 15 hours. c. The aircrew has completed three consecutive maximum crew duty days. The aircraft commander will normally declare additional ground time up to 24 hours. ACP will not request him to accept less than 24 hours.

An allowable alert time span is established after the crew rest period during which the crew may be "alerted" for a mission. Alert will normally be one hour prior to the time aircrew members must report to begin predeparture duties. The alert time span starts at the anticipated mission reporting time and lasts for 12 hours, after which if the crew is not alerted, an additional 12 hours inviolate crew rest will be given. Aircrew reporting time will not be earlier than the time at which the aircraft and cargo are ready for loading by the loadmaster and the aircraft is ready for preflight accomplishment by the remainder of the aircrew members. If a crew is alerted and it is subsequently found that an aircraft is not in commission or otherwise capable of departure within six hours after the crew reports to a designated place of duty (ACP, base operations, etc.), the aircrew will be returned to crew rest. Exceptions may be made.

The 40641 mission itinerary allowed for full crew rest per MAC directives and regulations.

MAC 40641 Accident: Apodeictic Explanation

This analysis is taken pretty much as is from its original source, the Air Force Safety Investigation Board's analysis and presentation of the facts in Part I of the AFR 127-4 report. I have made a few clarifications or comments where helpful, and have in a few spots combined or meshed some redundant information. You should note the thoroughness of the investigation in its explanation of the facts related to this accident.

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76 Although not a factor in this case; it is enlightening to point out that regulations such as these may be waved by Air Force authorities. This was done for Operation Desert Shield, where at the height of the airlift MAC crews were limited to 8 hours of crew rest.

History of the Flight

Routine Portion of Flight

The aircrew and aircraft were in the descent phase of the second leg of a cargo mission from Clark Air Base, Philippine Islands, to McChord AFB, Washington, when the accident occurred. (Mission Number PBP 654/079.) The aircrew was alerted at 1100z, 20 March 1975, for a 1415z departure. Mission preparation was routine and continued to McChord AFB with an en route stop at Yokota AB, Japan. The mission proceeded normally at FL370 until Vancouver Center cleared the aircraft to 15,000 and handed him off to Seattle Center. The Seattle Center controller identified MAC 40641 and issued radar vectors for the standard McChord arrival which is to vector the aircraft over the Olympic Mountains to remain clear of the Seattle terminal area. At 0548z, MAC 40641 descent clearance was amended to maintain 17 thousand and steer heading 160 degrees. At 0552z, MAC 40641 was cleared to 10 thousand and turned left to 150 degrees.

Crash Portion of Flight

MAC 40641 reported level at 10 at 0556z and was immediately cleared to maintain five thousand. MAC 40641 acknowledged five thousand, "40641 is out of ten," at 0556z [2256L, Thursday, 20 March]. This is the last recorded transmission from the aircraft.

The aircraft impacted the ground at 0558z [2258L, Thursday evening] on an estimated heading of 150 degrees magnetic, the last assigned heading received from the controller. The aircraft impacted at the 7,150 foot level of a 7,300 foot high ridge of Mt. Constance. The impact triggered a snow avalanche that buried much of the wreckage in the valley below. Ten crew members and six passengers were killed on impact. There were no survivors.

The plane was due to land at McChord at 2315L on 20 March 1975 (0615z on 21 March, GMT).

Rescue Effort

Seattle Center contacted the Coast Guard Station, Port Angeles, at 2307L[77] on Thursday, 20 March 1975 [0607z on 21 March 1975], about the suspected crash and the location of C-141 40641. Coast Guard personnel were airborned at 2349L with their helicopter and attempted a search of the area but were hampered by low clouds and high winds. The next search aircraft to arrive on the scene was an HC-130 Search & Rescue aircraft from McClellan AFB, California, and at approximately 0400L Friday morning, 21 March, the HC-130 received signals from an aircraft's emergency transmitter in the area where the aircraft was suspected of having gone down. As daylight broke, the search intensified, with helicopters from the Army, Navy, and Coast Guard trying to sight the downed aircraft. Search and Rescue teams from Seattle, Tacoma, and Bremerton, headed by Mr. Glen Kelsy from Bremerton, formed and were airlifted by helicopters to Quilcene Ranger Station to await additional instructions. Also on Friday morning, McChord's disaster response force, of approximately 25 personnel including doctors, radio operators, truck drivers, etc., left for Quilcene with snowmobiles and additional rescue equipment. The total search effort was hampered throughout by low cloud cover, rough terrain, high winds, and deep snow. Late Friday afternoon, about 1600L, Army and Navy helicopters, with part of a ground search team aboard, spotted aircraft wreckage, but weather and night fall ceased search operations. The total effort was moved from Quilcene to the Port Angeles Coast Guard facility. Saturday morning at 0828L, Army helicopters, a Coast Guard helicopter, and McClellan HC-130s continued to operate the search efforts, and shortly after 0930L an Army helicopter positively identified the wreckage on Mt. Constance at approximately the 5,900 foot level. Ground search and rescue forces landed at the site Saturday

77 The report switches to local time for the discussion of the rescue effort.

morning at 0928L[78], after setting charges to check for avalanche conditions. Members of the accident board were able to fly over the land at the site, and take photos of the area. Shortly after 1130L, the weather deteriorated and recovery actions ceased for the afternoon. Sunday morning at 0736L, search and rescue teams were back at the site. Weather conditions again became severe around 1110L, which caused the crews to withdraw from the area. Numerous small items had been located and were returned with the helicopters, and additional wreckage was spotted at about the 7,000 foot level.

Monday morning [24 March] the weather was 6,000 scattered, light rain, variable winds, and clearing. At 0928L a recovery team, including four mountain rescue people, four Air Force para-rescue men, and two park rangers, landed at the scene. These men began at the 5,000 foot level and started working their way up the mountain, searching for additional aircraft pieces and personnel. The team established a base camp at the site and remained overnight in the area. The recovery team began again on Tuesday, but due to eight inches of new snow and the threat of avalanche the team was airlifted out in the early afternoon. The team did locate the remains of one crew member, Lt Colonel Richard B. Thornton, navigator, still in the navigators seat. Because of snow, rugged terrain, and increased avalanche danger, the decision was made to discontinue further recovery operations until late spring. Agreements were made with appropriate local agencies for security of the wreckage area. The site would be checked and sampled twice weekly to ascertain when the operation may resume.

A full documentation of the rescue and recovery effort is presented in an appendix to this chapter.

Impact Area/Wreckage Distribution Analysis

The aircraft impacted in a descending flight attitude (estimated to be 1450 feet per minute) on a heading of 150° magnetic. The initial impact point was on a rock ledge at the 7,150 foot level on the Northwest face of Mt. Constance. The ridge at this point has an elevation of 7,300 feet and slopes upward and to the left of the impact point to an elevation of 7,743 feet. [367] The aircraft began breaking up upon initial impact. The aircraft continued up the slope to a secondary impact point at the 7,250 foot level. Total aircraft break-up occurred at this time. The cockpit area slid down the face of the mountain and became entrapped in a rock crevis approximately 500 feet to the right of the initial impact point. The impact triggered a snow avalanche which carried the remainder of the wreckage down the slope of the mountain and into the valley below which is at the 5,300 foot level. The backwash of the avalanche continued up the far side of the valley. The number one engine, pylon and part of the left wing were at the initial impact point. At the 5,900 foot level a bench was formed in the snow. Much of the aircraft wreckage was located on the bench area. The left wing tip section, twenty feet long, was located in this area and showed signs of charring which indicated a possible flash fire at the time of impact. The aircraft struck the rock face, right wing first which pivoted the aircraft to the left. The rock face where the right wing impacted showed signs of charring and the snow area to the left was covered with carbon smudge deposits indicating a possible flash fire impact at this point. Some of the other items located on the bench area are as follows (Starting at the highest level and working down): The center wing section, the flight data recorder, nose landing gear, number three engine, both main landing gears and the center wing box and part of the right wing. The wreckage at the lowest level included fuselage sections, number two and four engines, the hayloft area[79], CPI, and T-tail. The T-tail section was examined and the horizontal stabilizer was trimmed at zero degrees. There was evidence of a fire in the cockpit area possibly caused by rupture of the crew oxygen system. At the time of

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78 The time inconsistencies, positively identifying the wreckage shortly after 0930L and landing forces at the site at 0928L, are in the Board's report.

79 The hayloft is the area directly aft of the flight deck and above the front of the cargo section; the area is used to store crew baggage and has a rudimentary bunk for a crew member to catch some in-flight rest.

impact the aircraft commander, Lt Evans, was in the left seat; Lt Arensman was in the right seat; Capt Eve was in the flight-examiner check ("jump") seat; Lt Col Thornton was at the navigator's station, and TSgt Campton was at the flight engineer's panel.

Weather Analysis

The estimated weather at the impact site in the Olympic Mountains at the time of the accident was layered clouds from the surface to 15,000 feet. Visibility less than one fourth of mile in clouds and light snow. Winds from the south at 25 knots. The temperature estimated 23 degrees Fahrenheit[80] and dewpoint 19 degrees. Altimeter setting 29.78 inches. Weather was not considered a factor in this accident.

Aircrew Analysis

The aircrew was found to be current and qualified in accordance with Air Force and MAC directives to perform their respective duties. The mission required an augmented crew in accordance with 22nd Air Force Operations Policy. The following crew members are listed by crew position for this flight.

Aircraft Commander: 1Lt Earl R. Evans, age 27, 8MAS, 62MAW, received his initial pilot rating on 9 June 1972. His primary and duty AFSC[81] is 1045L, pilot aeronautical rating, qualified aircraft commander. As of 21 March 1975, he had accumulated 1363.9 flying hours of which 1182.7 were in the C-141A; total weather instrument hours 396.9. His last flight evaluation, a no-notice evaluation, was completed satisfactorily during an operational mission from Yokota AB to Kadena AB and return on 12 January 1975. His training and medical records were reviewed and no discrepancies or problems were found. He was qualified and current in accordance with all Air Force and MAC directives to perform his assigned duties as a C-141 aircraft commander.

Copilot: 2Lt Harold D. Arensman, age 25, 8MAS, 62MAW, received his initial pilot rating on 27 July 1974. His primary and duty AFSC is 1043L, pilot aeronautical rating, qualified copilot. As of 21 March 1975, he had accumulated 379.3 flying hours of which 179.3 were in the C-141A; total weather instrument hours 24.8. His last flight evaluation, an initial copilot evaluation, was completed satisfactorily on 19 November 1974. His training and medical records were reviewed and no discrepancies or problems were found. He was qualified and current in accordance with all Air Force and MAC directives to perform his assigned duties as a C-141 copilot.

Additional Pilot: Captain Frank A. Eve, age 27, 8MAS, 62MAW, received his initial pilot rating on 4 May 1972. His primary and duty AFSC is 1045L, pilot aeronautical rating, qualified aircraft commander, serving as an augmenting crew member (copilot) on this flight. As of 21 March 1975, he had accumulated 1529.6 flying hours of which 1343.4 were in the C-141A; total weather instrument hours 304.1. His last flight evaluation, a no-notice evaluation, was completed satisfactorily during an operational mission from McChord AFB to Elmendorf AFB on 17 November 1974. His training and medical records were reviewed and no discrepancies or problem areas were found. He was qualified and current in accordance with all Air Force and MAC directives to perform the duties of a C-141 aircraft commander.

Navigator: Lt Colonel Richard B. Thornton, age 40, 62MAW/DOT, attached to the 8MAS for flying, received his initial navigator rating on 20 May 1960. His primary AFSC is 2275Y and secondary is 1545L, senior navigator aeronautical rating. As of 21 March 1975, he had accumulated 3328.5 flying hours of which 393.0 were in the C-141A. His last flight evaluation, an annual qualification evaluation, was completed satisfactorily on 13 November 1974. His training and

80 The accident investigation report stated "centigrade," which is obviously in error.

81 *Air Force Service Code*, referring to assigned duties the individual is qualified for; e.g. 1045L is pilot, 1043L is copilot.

medical records were reviewed and no discrepancies or problem areas were found. He was qualified and current in accordance with all Air Force and MAC directives to perform the duties of a C-141 navigator.

Additional Navigator: 1Lt Stanley Y. Lee, age 25, 8MAS, 62MAW, received his initial navigator rating on 31 October 1973. His primary and duty AFSC is 1545L, navigator aeronautical rating, serving as an augmenting crew member on this flight. As of 21 March 1975, he had accumulated 963.6 flying hours of which 779.1 were in the C-141A. His last flight evaluation, a no-notice evaluation, was completed satisfactorily during an operational mission from Clark AB to Yokota AB on 6 July 1974. His training and medical records were reviewed and no discrepancies or problem areas were found. He was qualified and current in accordance with all Air Force and MAC directives to perform the duties of a C-141A navigator.

Additional Navigator: Lt Colonel Ralph W. Burns, Jr., age 42, 62MAW/DOVN, attached to the 8MAS for flying, received his initial navigator rating on 22 August 1957. His primary AFSC is M2245L and secondary is M1545L, master navigator aeronautical rating, qualified and serving as a flight examiner navigator on this flight. As of 21 March 1975, he had accumulated 7549.8 flying hours of which 1504.2 were in the C-141A. His last flight evaluation, an annual qualification evaluation, was completed satisfactorily during an operational mission from Elmendorf AFB to Yokota AB on 16 December 1974. His training and medical records were reviewed and no discrepancies or problem areas were found. He was qualified and current in accordance with all Air Force and MAC directives to perform the duties of a C-141 navigator.

Crew: The records of the remainder of the crew were reviewed and no discrepancies were noted. The crew was current and qualified in accordance with Air Force and MAC directives to perform their respective duties. The only waiver granted this crew or aircraft was a two-hour crew duty time extension to SSgt Peter Arnold, lLM. The flight crew was augmented in all positions except the loadmaster's; therefore, the crew could continue Yokota to McChord as scheduled with six passengers. The flight crew had A1C Robert Gaskin, loadmaster unqualified, who it felt, along with augmenting crew members, could aid SSgt Arnold with his passenger responsibilities if necessary.

Aircraft Analysis

Flight Data Recorder Analysis

The flight data recorder was recovered from the wreckage on the bench area and was brought to the NTSB Flight Recorder Laboratory on 12 June in Washington, D.C. The recorder had been subjected to moderate crushing damage, particularly in the area of the electronics chassis, and the outer case had been torn open on the upper side. There was no evidence of exposure to fire, heat or smoke. The foil medium magazine was removed through the front access door for examination. The foil was undamaged and all parameter traces had been recorded in a clear and active manner. The analysis of the tape by the NTSB indicated that the recorder stopped functioning for unknown reasons, after 8 hours and 28 minutes into the 9.3 hour flight, even though the unit was still powered and sufficient tape was available. This occurred 49 minutes prior to the crash. At the time of stoppage the indications were: 37,100 feet; 240 KTAS; 1 G; and 110 degree heading. No information was received from the aircrew concerning maintenance being required on the flight data recorder, and none of the parameters required to illuminate the annunciator light were present. The crew was probably not aware of this malfunction. An Unsatisfactory Materiel Report has been submitted on the flight data recorder.

Simulated Flight Profile of MAC 40641

A local mission was flown on 28 March 1975 in an attempt to reconstruct the descent portion of C-141 aircraft 40641. The mission profile was coordinated in advance with Mr. Robert Porterfield, McChord FAA representative and Seattle Center.

Route: Aircraft departed McChord AFB on radar vectors to Port Angeles. As aircraft approached Port Angeles, Seattle Center was requested to vector aircraft onto the final portion of the track flown by #40641. This resulted in a vector to a point just North of Port Angeles for track alignment. From that point aircraft was vectored by Seattle Center over track flown by #40641. Initial vector heading was 160° magnetic and aircraft altitude for first run was 10,000 feet MSL. Seattle Center changed vector heading to 150° magnetic at the point where #40641 had changed heading and it is also the point where clearance was issued to #40641 for descent from 10,000 feet MSL to 5,000 feet MSL. This final vector heading, 150° magnetic and 10,000 feet MSL altitude, was maintained until after passing the impact area. After passing the impact area, vectors were requested for another run. Route and vectors were identical to the first run. The only exception was in altitude. Second run was initiated at 10,000 feet MSL. At the point where #40641 was given clearance to 5,000 MSL, a descent was initiated to 8,700 feet MSL (VFR) and the remainder of the track to the impact area was flown at this altitude. After passing impact area, request for a hard altitude and radar vectors to McChord AFB was initiated. The time from over the site to a geographic point where a lower altitude could be accepted was timed at two and one-half minutes. Aircraft was vectored to McChord AFB for landing and mission termination.

Weather: Port Angeles to impact area -- clear, no restrictions to inflight visibility.

Navigation Aids: The navigation aids analyzed were the aircraft APN-59B Search Radar, TACAN/VOR, and the Low Altitude Radar Altimeter.

a. The APN-59B radar antenna stabilization was deactivated (switch position to "off") to try to simulate an actual "antenna stab. inop." condition. During constant heading flight, no degredation of the radar scope presentation was experienced. During turns, especially greater than 30° bank angles, the scope presentation became unusable for radar navigation/terrain avoidance. The antenna tilt was also directed to both limit extremes (full up and full down) to try to simulate another "antenna stab. inop." situation. The scope presentation became unusable during these conditions.

b. Both TACAN and VOR receivers were tuned on McChord and/or Seattle. At the altitude flown (10,000' and 8,700'), no degradation of TACAN/VOR reception was experienced during both runs. One exception occurred prior to the second run on the turn inbound, over the Strait of Juan de Fuca. TACANs were tuned to McChord and unlocked during the turn. This is a common occurrence when the TACAN antenna becomes blocked by the aircraft frame during a turn. It should also be noted that the TACANs were tuned during straight and level flight, and immediate and firm lock-on resulted.

c. During both runs the low altitude radar altimeter was on and the altitude trip marker was set at 1,000 feet. Only once, on the second run at 8,700 feet MSL, did the radar altimeter give any indication of terrain proximity. This indication was a momentary movement of the altitude pointer from the 2,500 foot point (from behind the flag mask) to the 2,300 foot point and return.

Conclusions: Conclusions from the equipment operation tests in the simulated flight are as follows:

a. The aircraft radar is usable for navigation/obstacle avoidance when antenna stabilization is off. However, certain antenna stabilization malfunctions (e.g., stabilization gyro tumbled, causing radar antenna to become locked at an extreme limit) render the radar unusable for navigation/obstacle avoidance.

b. The TACANs/VORs remained locked on for this particular flight; however, TACANs/VORs installed in other aircraft can behave totally different.[82]

82 Testimony in the Collateral Investigation from a First Lieutenant pilot described the following experience while he was over the same Olympic Mountain area returning from Yokota a few days later: "[Seattle Center] gave us a clearance out of 10,000 at about 38 DME [from McChord]. I remember that the TACANs didn't lock on when I first dialed them in. It is possible that the TACANs didn't lock on that day [of the accident], which would give them a question as to how far they were from McChord at the time of the clearance that they received."

c. The radar altimeter, due to the rough terrain and indication time lag, did not supply usable information for terrain avoidance on this mission profile.

Maintenance Record and Other Equipment Problems

The on-board aircraft maintenance log, AFTO 781 binder, was not recovered from the crash site. However, it is standard operating procedure for the aircrew to radio in their "Inbound Status" report (MAC Form 278b) containing maintenance problems enroute to their destination. This report was reviewed by the maintenance member of the accident board. Of the six maintenance items, only one was relevant to the flight deck operation for this portion of the flight, the APN-59 radar.[83] The maintenance discrepancy code called in for this item was 90A, which in MAC Reg 66-7 refers to "Radar (APN59) Antenna tilt inop." However, there is some uncertainty as to the exact nature of the radar antenna problem because the breakdown of the code recorded in the remarks section of the MAC Form 278b is written "Antenna stab inop."

From a review of maintenance debriefing logs (MAC Form 278) at the various stops enroute, it is apparent the APN-59 radar on 40641 has had a history of problems. On these logs "only safety of flight and mission essential/contributing discrepancies will be debriefed at enroute station and while transiting home station." At Hickam AFB, Hawaii, two discrepancies regarding the radar were recorded as "Radar tilt needs adj." and "APN 59 weak reception." Maintenance response entries for corrective action indicate "Adjusted tilt control - op ck ok" and "Adjusted video gain - op ck ok," and the aircraft was signed off "OK." At Yokota AB, Japan, a single entry regarding the radar noted "APN 59 Inop." At Yokota the maintenance indication was a discrepancy recorded as "APN 59 Antenna Inop." Maintenance work on the radar ceased exactly at the "estimated time in commission" (ETIC) recorded on the

83 The APN-59 radar is the only airborne radar on the C-141A; it is located at the navigator station and is used both for navigation and weather avoidance, with a repeater scope mounted on the front panel between the two pilots. En route the radar is used for severe weather avoidance and navigation via bearing and distance to identifiable land forms, such as islands. During the descent and approach phase of the flight, the navigator is supposed to use the scope to monitor terrain. Terrain patterns on the radar behave like light reflections from a spot light with obstacles in front of it. Radar is "line-of-sight" only; that is, it can't see over hills or around corners. When above the terrain, the dark radar "shaddows" come together behind the bright mountain reflections (in a cone shape for an idealized mountain) such that you get more "returns" showing up beyond the shaddow further behind the mountain. When at the same altitude as the peak of a mountain, the shaddow form has parallel sides; and, when below the elevation of the peak of a mountain, the shaddow fans out and you get no returns behind the mountain. Thus, with the course indicated on a properly operating radar screen, you have a vivid information source regarding your proximity and altitude relative to the terrain.

arrival maintenance status log, with 1 hour and 45 minutes of labor logged on the problem and corrective action designated as "C/F By Crew," meaning "carried forward" to home base by crew.[84]

Navigational Aids Analysis

Navigational aids pertinent to the flight path on MAC 40641 are: Neah Bay NDB, Port Angeles VOR, Seattle VORTAC/DME, Paine VOR-LOM, McChord VORTAC, and Seattle ARTCC ARSR (Primary and Secondary Radar); with relevant airways J523, V23, V4. The navigational aids providing course guidance and DME Northwest of McChord are FAA operated and maintained, with the exception of the McChord VORTAC (which is USAF operated and maintained.) Special flight checks performed subsequent to the C-141 accident indicated NAVAIDS were operating within operational tolerances and were determined satisfactory.

Pertinent charts available to the aircrews are basically Department of Defense Flight Information Publications -- (DOD Flip) enroute low and high altitude charts and instrument approach procedures (IAP's) for McChord predicated on the VORTAC and ILS and contained in DOD high and low IAP charts for Northwest United States. Minimum altitude information: i.e., minimum enroute altitude (MEA), minimum obstruction clearance altitude (MOCA), minimum reception altitude (MRA), spot elevations and sector altitudes, are oriented to the designated airways structure and immediate vicinity of the terminal area. The terminal charts depict only selected obstructions, spot elevations (within 10NM) and minimum sector altitudes within a 25NM radius of the terminal reference point. A convenient reference to off-airway terrain is not provided by the aforementioned products. Pilots deviating from the airway structure on radar vectors do not, as a rule, possess a DOD published chart product that enables a convenient organziation of charts and ready references in the cockpit depicting significant terrain characteristics and backup course guidance en route descent phases of flight. A basis is not provided for pilots to challenge or otherwise question air traffic control altitude assignments relative to terrain while being radar vectored.

Air/Ground communications were considered satisfactory. Seattle experienced difficulty in establishing initial contact with MAC 40641. However, once established, two-way contact was reported "loud and clear." Frequency interference, atmospherical conditions or erratic communications are not considered an attributing factor in the accident. Communication capabilities for air traffic control purposes in the Seattle/McChord area are considered adequate for the air traffic level serviced.

Air Traffic Control Analysis

The air traffic control analysis below was performed by the NTSB in cooperation with the FAA. Agencies making transmissions and abbreviation of each are provided in the following table.

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84 Collateral Report testimony indicates that the crew navigators elected not to have the weather radar repaired after they learned how long it would take. The radar repairman was unable to work on the radar during refueling which explains the lack of progress in 1 hour and 45 minutes. Both navigators, the report said, elected to take the aircraft as it was, and changed the entry on the Form 781A from 'mission essential' to 'maintenance convenience.' The Investigating Officer's summary states that the weather en route to home station did not indicate the presence of any violent weather directly along the route, so this would not be an unusual practice if the aircraft commander felt that the mission could safely be completed. The report concludes that there was no indication from the crew or from expert maintenance and operational testimony that any of these discrepancies or the culmination of these discrepancies would degrade the flying capability of the aircraft.

Table 8.4 ATC Communication Identifiers.

Agency	Abbreviation
Seattle ARTCC Sectors D3/R3	SEA D3
Seattle ARTCC Sector D2	SEA D2
Seattle-Tacoma Airport Traffic Control Tower	SEA TWR
Vancouver Area Control Center	VR CTR (ACC)
Whidbey Radar Air Traffic Facility	NUW
Northwest Airlines Flight 26	NW26
Whidbey NAS A6 Navy 28323	V28323
Canadian Civil CFJLJ	CFJLJ
Military Airlift Command 40641	M40641

Air Traffic Control Facilities

The Seattle Air Route Traffic Control Center, commissioned and operated by the United States Federal Aviation Administration (FAA), Department of Transportation (DOT), provides en route air traffic control services to all aircraft operating in accordance with (IAW) instrument flight rules (IFR) within the five state area of Washington, Oregon, Northern California and Western Montana and Idaho, in addition to an offshore Pacific area extending approximately 125 miles from the Washington-Oregon coastal boundaries. The area encompasses approximately 285,000 square miles of airspace. Services are principally based on long range radar inputs as derived from sites located at Seattle (Ft. Lewis), Spokane, Klamath Falls, and Salem. Radar data is transferred to the center facility, located in Auburn, Washington in digitized form through direct access telephone lines. The Seattle ARTCC was commissioned an operational National Airspace System (NAS) Stage A facility on 4 September 1974, at which time a capability was established to enter the radar data derived from the four sites previously identified, into an automated complex centering on an IBM 9020 computer. This radar processing capability provides controller access to information via computer programming and automatic readout on scope displays, which were previously provided by a manual means. Such information may consist of aircraft identification, altitude readout (translation of transponder mode 3c interrogations), and air speed. Other data and capabilities are provided by the Stage A system. They are not elaborated on herein except where pertinent, because of the irrelevance of the technical details of the system to this investigation.

Currently, the NAS Stage A System is normally employed on a daily basis between 0600L and 2200L. The remaining time is used for testing or validating on-going computer programs relevant to air traffic control and re-certification of the equipment (attesting to its accuracy of operation).

During the period from approximately 2200L-0600L en route control is provided utilizing direct (non-processed radar) raw video and mode 3A transponder interrogations. Aircraft identification and altitude information are manually entered on a plastic target marker or "Shrimp Boat," which is placed on the horizontal indicator or Planned View Display (PVD) in relation to the raw video or transponder target it identifies.

In accordance with Seattle ARTCC Order ZSE 6100.12 issued on 21 May 1974, Section 111, para b2b, the radar display (PVD) will be placed in the horizontal position when controlling by non-processed radar thereby enabling the use of "Shrimp Boats" on the radar display. The PVD is normally used in the vertical position when computer processed or NAS Stage A radar is being used to control traffic. Because of the narrow definition of radar data presented in the NAS Stage A Configuration, as opposed to wider definitions presented by non-processed radar, NAS Stage A is commonly referred to as "Narrow Band Radar." Non-processed radar is commonly referred to as "Broad Band Radar." En route air traffic control is provided by application of procedures and techniques contained in FAA Handbook 7110.9D and facility orders pertinent to the center. [Seattle ARTCC orders are attached to the Air Force Safety Investigation.]

Airspace and Seattle ARTC Center Coordination with McChord RAPCON

Coordination is accomplished by letter of agreement between the FAA Chief, Seattle Center, and the McChord Chief, Radar Approach Control (RAPCON). The purpose of the letter of agreement is to outline procedures used in providing terminal area control services for all airports within the airspace permanently delegated to McChord RAPCON and en route aircraft transiting that airspace. It is supplementary to current En Route and Terminal Air Traffic Control Handbooks. The agreement is distributed to appropriate facility personnel of Seattle ARTC Center, McChord RAPCON, and the Regional Air Traffic Division.

The Letter of Agreement relevant to this investigation is dated 15 November 1973. It was ammended with temporary changes in delegated airspace and arrival and departure procedures through a Supplementary Interim Letter of Agreement, dated 15 August 1974. This authorized new procedures to be used during an evaluation period not to exceed 120 days (15 December 1974), which, if proven satisfactory, would be incorporated in a new Letter of Agreement. On 16 December 1974, a memo extended the Supplementary Interim Agreement until 15 March 1975; on 13 March 1975 a second memo extended the interim procedures until the new Letter of Agreement, then in the process of being finalized, becomes effective.

The 1973 Letter of Agreement arrival procedures specified that arrivals shall be positioned in the handoff area at or descending to 8000 feet, unless coordinated with RAPCON prior to issuing a different clearance. The 1974 Supplementary Agreement ammended arrival procedures to restrict arrival routes to the handoff area at 10,000 feet and above, and to require ARTCC Sector 2 to ensure that arrivals are positioned and level at 10,000 feet prior to handoff, unless coordinated with RAPCON prior to issuing [a different] clearance.

Air Traffic Conditions

Air traffic was considered light by judgments of the controllers interviewed by the accident investigation board. A total of four (4) aircraft were being controlled by the sector controller. The sector involved is designated Seattle North. Controller positions incident to the handling of MAC Flight M40641 are designated R3 and D3 (Radar and Data control positions). Positions R3/D3 were combined and manned by one journeyman radar controller during the period from 0540z, 21 March, [2240L, 20 March] until approximately 0604z.[85] This method of staffing, during conditions when traffic is considered light, is not considered unusual or abnormal by ARTCC personnel interviewed.

Resume of Flight

For the purposes of the ATC analysis, only that segment of flight is addressed commencing at 0545:36, 21 March 1975, at which time MAC 40641 was handed off to Seattle ARTCC and radar contact acknowledged by the Seattle North sector position D3. Hand off point was approximately 15NM on radial 294 of the Victoria, B.C. VOR. Vancouver advised that MAC 40641 had been "cleared to fifteen." Subsequent contact with MAC 40641 clarifies "fifteen" as fifteen thousand feet. On initial radio contact with Seattle at 0546z, MAC 40641 indicated passing 32,000 (FL320) for one five thousand. At this time Seattle advised MAC 40641 to (Squawk) ident and fly a heading of 150 (degrees) vectors to McChord runway one six and to expect a precision radar (PAR) approach. This information was not acknowledged by MAC 40641 until 0548:50z due to communications difficulties with Seattle and after several attempts by both the aircraft and the center to reestablish radio contact. At 0548:50z Seattle issued and MAC 40641 acknowledged 160 (degrees) vectors PAR McChord. Seattle immediately advised MAC 40641 to maintain "one seven thousand" and to expect a lower (altitude) in thirty miles. MAC 40641 acknowledged instructions to "stop at seventeen." At 0549:18z MAC 40641 was provided and acknowledged the McChord altimeter

85 MAC 40641 went down at 0558z, or 2258L.

setting. At 0552:18z MAC 40641 advised Seattle that he was level seventeen (thousand). At this time MAC 40641 was cleared to one zero thousand and advised to turn left to one five zero (degrees). MAC 40641 acknowledged.

At 0556:16z MAC 40641 advised Seattle "level at ten" (thousand). Seattle responded in advising MAC 40641 to maintain five thousand. MAC 40641 acknowledged by stating "five thousand four zero six four one is out of ten" (thousand).

ARTCC position R2-D2 monitored the progress of MAC 40641 from the vicinity of discovery intersection to a point on their radar display correlating with Mt. Deception and/or approximately 0600z at which time the R2 controller lost both primary and secondary radar contact.

At 0556z or last radio contact point, MAC 40641 had progressed approximately 57 NM from hand off point (Vancouver ACC to Seattle ARTCC) in a South-Southeast direction. This is approximately 13 NM NNW of the accident site.

Communications Analysis and ATC Procedures[86]

The tape transcripts provided by the Seattle ARTCC contain recorded information of Seattle north sector positions R3/D3. These radar and data positions had been combined at approximately 0530z. Interview with the controller assigned to positions R3/D3 indicated, in his judgment, traffic was "light." Further review of the transcripts for the period commencing at 0545z and ending 0600z, indicate the controller transmitted information 60 times and was directly involved with a total of 113 radio transmissions during this 15 minute span. During this period, the transcripts reflect unawareness to any control problem excepting some difficulty in establishing initial two-way communications with MAC 40641.

The traffic situation, in terms of numbers of aircraft in the system, four, and altitudes available, enabled a significant latitude of control actions at the disposal of the controller toward preventing any compromise of separation standards. Radio contact was attempted with M40641 by R3/D3 when the aircraft was 45 NM north of the Vancouver ACC/Seattle Center boundary. It is conceivable that this may have attributed to difficulties with M40641. Position R3/D3 transmitted and received 33 communications to/from M40641 or from other sources directly related to attempts to establish initial communications with and issue initial control instructions to M40641 during an approximated 11 minute period.

Initial control instructions to M40641 were normal with respect to other traffic. Routings (vectors) issued were considered normal for approaches into McChord AFB from the northwest. At 0556:16z MAC 40641 reported level at 10,000 feet. At 0556:25 Seattle advised "40641 maintain 5,000." This clearance is not indicated on the flight progress strips of MAC 40641; the strips show changes in altitude clearance (which are in hundreds of feet) from 370 to 170 to 150 to 100.

Based on the ground speed entered on the flight progress strips of MAC 40641 and the heading (vector) assigned by Seattle Center, establishes the position of MAC 40641 in an area where the minimum terrain clearance altitude (and Seattle ARTCC minimum vectoring altitude) is fixed at 10,000 feet or 2,000 feet above the highest terrain. MAC 40641's acknowledgement of "five thousand" "out of ten" at 0556:25 is the last recorded transmission from that aircraft.

During the time frame 0545z and 0600z, position R3/D3 was also controlling a Navy aircraft proceeding to Whidbey Island NAS from the southeast (YKM VORTAC 255/35, SEA VORTAC 025/42). Navy V28323 was cleared to descend to 10,000 feet at 0553:22 at pilot's discretion. MAC 40641 had been cleared to "one zero thousand" exactly one minute earlier.

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86 Exerpts from the transcript of actual voice transmissions contained in this portion of the safety report were presented at the beginning of Chapter 1. This Safety Board's analysis is based on that transcript, interviews with the controllers, and offical ATC procedures. The full radio communication transcript is given in the Appendix.

The Navy 28323 and MAC 40641 were not traffic in respect to each aircraft's position. It is noted that hemisperical altitude assignments[87] were not being observed in the case of the MAC aircraft. Additional traffic for the R3/D3 controller consisted of an aircraft of Canadian registry (CFJLJ) proceeding at 16,000 feet on approximately a true north heading from over Olympia direct to Vancouver. CFJLJ was traffic affecting M40641's descent and cause for amending M40641's assigned altitude from 15,000 to 17,000.

At 0553:51 Seattle accepted a hand off from Vancouver on NW26, 5 NM west of Victoria, descending to 15,000. Seattle ARTCC progress strips indicate NW26 was en route from Alaska over Victoria J502 to Seattle.

The time element and altitude assignments provided separation between NW26 and CFJLJ. At 0556:48 Seattle cleared NW26 to "niner thousand" (9000). NW26 acknowledged.

At 0554, Saturn 10 departed Boeing Field, Seattle. Progress strips indicate an assigned altitude of flight level 200 and routing to Vancouver via Bellingham and J50.

At 0558:35 Navy 28323 reported, "level ten thousand." Seattle (R3/D3) responded "28323 level at five."[88] [368] Navy 28323 replied "negative, level one zero thousand." At this time Seattle cleared V28323 to descend to 5,000. Progress strips, indicate that the controller recorded the 5000 clearance he unintendedly gave to the Air Force plane on the strip for the Navy plane, which show changes in altitude from 220 to 100 to 50 (hundreds of feet).

At 0558:57 Seattle D3 approved an on course (climb) for Saturn 10. This action headed Saturn 10 in a northerly direction and could be projected as significant traffic or a potential conflict with NW26 descending to 9,000 feet on a heading of 120 degrees for Runway 16 Seattle. At 0600:04 Seattle position D2 queried R3/D3 on the whereabouts of MAC 40641. R3/D3 indicated he forgot to "ship him to you -- standby." D2 asked "where is he though?" At this time R3/D3 began calling MAC 40641 at approximately 20 second intervals. Seattle also asked NW26 to attempt radio contact with MAC 40641.

At 0600:23 position R3/D3, in what appears in the transcripts as a response to position D2 regarding the location of MAC 40641, advises D2 of seeing him (M40641) "one fifty heading down by Bremerton."

This statement is not substantiated by any previous transmission made by position R3/D3 or to R3/D3 from other sources in relation to a radar target in the Bremerton area.

At 0601:36 Seattle tower advised of "someone about 20 north of Lofall intersection at 'ten seven' (10,700 feet) descending."

This demonstrates capabilities of the Seattle tower/approach control facility to observe mode 3c altitude readouts with ARTS III. This capability comes into use later in assuring R3/D3 of vertical separation between NW26 and Saturn 10.

At 0602:43 Seattle advised NW26 to turn right heading 160 cleared to nine thousand. This was the second clearance given to NW26 to maintain 9,000; the first being issued approximately six minutes earlier.

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87 West bound planes flying at even altitudes and east bound at odd altitudes.

88 For interpretation, it is significant that the board's analysis shows this phrase as a declarative instead of a question. As a declarative it indicates another "slip" by the controller in correctly hearing the Navy transmission ("five" versus "ten"). As a question, it indicates the controller thought the Navy plane should be calling level at five, the clearance he was sure he gave it. The full transcript does contain the question mark. Also, at least three investigative reporters who heard the actual tape when the FAA released it described it as a question. One stated, "With obvious surprise, controller SEA D3 asked, 'Two-eight-three-two-three level at five (thousand)?'" Another wrote, "'28323 level at five?,' the air controller questioned, puzzlement obvious in his voice." And a third described the Navy transmission of "level ten thousand" as a "disturbing message" to the controller; the non-verbal character of his response conveying that "This couldn't be! The controller knew he had directed him to 5,000. The pilot must be mistaken."

This action indicates a deficiency in recording control information when it is initially passed to the aircraft being controlled. This is indicated in R3/D3s discussions with Seattle tower at 0602:54 and 0602:57. At 0603:05 R3/D3 advised Seattle tower "that's the *MAC* coming to nine." The traffic 10 north of Lofall approximated the relative position of NW26, that had (on two separate occassions) been cleared to 9,000 feet. During the interview with R3/D3 controller, he stated probable confusion between V28323 and MAC 40641. The transmission at 0603:05 indicates confusion of NW26 with MAC 40641. This was subsequent to his being queried by D2 about MAC 40641's location.

At 0603:23, R3/D3 effected hand off of NW26 to Seattle tower, 10 north of Lofall descending to nine thousand, turning right to 160.

The transmission by Seattle tower at 0603:32 regarding radar contact on the *MAC* appears to present a question rather than a declaration. Subsequent transmissions reviewed fail to correlate this transmission with a radar target.

During the period, the R3/D3 position controller worked the aircraft referred to in the above analysis with his planned view display (PVD) in the vertical position, although broad band (non-computer processed) radar was being utilized. In this configuration, the PVD precluded use of "shrimp boats" thereby compromising to full control capabilities designed for a broad band operation. Use of the vertical configuration for broad band radar control conflicts with Seattle ARTCC Order 6100.12, May 21, 1974, and FAA Handbook 7110.9D, Chapter 4, Section 3, Part 671.

Also during the period for which transcripts are available, there are no indications of altitude information on MAC 40641 being passed to position D2. This practice appears, on the surface, to be inappropriate in accurate accountability for all control aspects of the flight, especially during the use of broad band radar.

FAA Press Release: 1000L, 24 March 1975[89]

The crash of an Air Force C-141 jet transport on March 20, appears to have been caused by human error by an air traffic controller who inadvertently radioed descend instructions to the Air Force airplane instead of a Navy aircraft he was also controlling, it was announced today by Alexander P. Butterfield, Administrator of the FAA, following the FAA's own preliminary investigation.

Butterfield expressed extreme regret over the tragedy.

The Air Force airplane, a part of MAC, was on a flight from Japan to McChord Air Force Base, Washington. The Navy aircraft, an A-6 was en route from Pendleton, Oregon to Whidbey Island. Both airplanes were under the control of a fully qualified controller at FAA's Seattle air route control center.

Both aircraft were at 10,000 feet about 60 miles apart, with the Air Force airplane heading South and the Navy heading North. The controller identified the Navy A-6 on his radar scope and wanted to instruct it to descend to 5,000 feet, but instead of calling "Navy 8323" he radioed "MAC 0641." Then, soon after, the controller realized the error, but the C-141 had already disappeared from the radar scope and had crashed in the Olympic Mountains, where the terrain raises as high as 7,900 feet.

The FAA preliminary investigation was headed by William Flener, Associate Administrator for Air Traffic Management and Airway Facilities, who was sent to the scene by FAA Administrator, Butterfield, and Secretary of Transportation, William T. Colman, both of whom took a personal interest in the matter. A separate military investigation to make a final determination is also being conducted in which the FAA is cooperating.

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89 This release, also quoted in Chapter 1, was based on initial findings from the analysis of the tape of controller communications by the FAA. The news release contains some inaccuracies in some of the details, but no further release was made subsequent to the above detailed analysis, since there was nothing to indicate the general conclusions had changed.

The FAA operates 20 Air Route Traffic Control Centers in the Continental United States, and in 1974, they handled more than 23 million aircraft operations.

Summary and Apodeictic Conclusions

The apodeictic "cause-and-effect" conclusions for this accident are indeed readily apparent and compelling. The primary cause clearly involved a human error in the descent clearance given to the MAC airplane, a clearance that was dutifully followed by the pilot in control. Further, the controller who made the error apparently failed to follow FAA procedures for using "broad band" raw video radar, which might have helped prevent the slip.[90] Having left his PVD (planned view display) on the vertical screen he was not able to use the plastic target marker "shrimp boats" as a way of tagging vital information like aircraft identification and altitude to the transponder coded radar returns. We do not know why a journeyman controller chose to operate in this fashion. It is evident he was cognizant of which altitudes the planes *should* be at, with the puzzlement that came over him when the Navy plane called "level at 10,000." It does not appear that he was inattentive, but that he made a cognitive slip of which he was not aware until the Navy call presented an incongruency.

Once a problem was identified ("where is MAC 40641") and the controller became preoccupied with it, however, the board's analysis indicates more confusion was evident. The confusion surrounding the situation was perhaps exacerbated because he had no "shrimp-boat" information to fall back on. From the transmissions we can tell that he believed he "saw him uh one fifty heading down by Bremerton," but it is unclear what he actually saw on the screen or whether this was the last return he remembered seeing. A second clearance was given to the Northwest flight, NW 26, "cleared to nine thousand," six minutes after the same altitude clearance was given initially. It is unkown whether he forgot that he already cleared NW 26 to 9000 or whether he was reaffirming the clearance along with a new heading he gave him; such follow-ups are not uncommon (the plane had yet to report or reach 9000). He also had not confirmed radar contact or he lost track of the Saturn 10 that departed Boeing Field, stating, "departure where is that Saturn?" This indicated at least the desire, if not the need, to locate and/or verify a target while still trying to locate the MAC.

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90 In the controller's written statement and that of his supervisor made to the Collateral Investigation Officer, however, there is no mention of this failure. We can only assume it was brought out in testimony to the Safety Board under the protection of confidentiality.

We do not know whether this was a "double checking" process he went through to confirm that a radar target was *not* the 40641, or whether it represented a loss of the Saturn target itself. Then he thought the traffic "10 north of Lofall" identified by Seattle Tower approach control radar was "the MAC coming to nine." This was actually traffic which approximated the relative position of NW 26.

There were no mitigating circumstances for the controller in terms of weather, work load, qualifications or his experience. Weather, although in the clouds and IFR, was not a factor and air traffic was considered light in the judgment of the controllers interviewed. The controller was a fully qualified journeyman. The use of broad band backup radar during the light traffic period of 2200L-0600L was a routine operating procedure, as was the combining of the Radar and Data positions, which occurred 18 minutes before 40641 disappeared from the radar screen. Neither procedure was considered unusual nor abnormal. Also, independent of minimum clearance altitudes due to terrain, with which the controller would have been aware, the Seattle/McChord RAPCON interim agreement specifying a 10,000 foot hand-off unless coordinated with RAPCON, had been in effect for seven months and thus represented no new changes in procedures. The Air Force plane had a crew which was competent and fully qualified. They were not in violation of any crew rest period or crew duty day time limitations. The mission preparation and flight were routine for this mission. The aircraft had a history of radar and navigational computer problems[91]; but, radar is not required for IFR flight and the navigation computer is needed used where there are no radio aids (e.g. over water)[92].

The aircrew, although having sufficient navigational aids to independently determine their position even without an operating radar, were under ATC control, meaning "radar vectors to McChord," with appropriate altitude clearances setting up for handoff to McChord RAPCON. The crew could be faulted for not knowing exactly where they were at all times, but "radar control" means just that -- "control" of the aircraft's route and altitude by clearances from the air traffic controller. If a pilot accepts radar control vectors, then headings and altitude clearances are not offered up as suggestions for discussion. It is assumed that the controller is managing multiple traffic and that these are directives to ensure safe flight, avoiding traffic conflicts

91 The aircraft has two nav computer, but only one was reported as inoperative.

92 Once on the continental airway system and/or under radar contact, the nav computer, whose output is in latitude and longitude, is not used as a primary nav aid to position the aircraft.

(horizontal and vertical), obstacles, terrain, restricted areas and so forth; all as part of the process of being lined up for a routine handoff to approach control and an instrument or vectored approach to the active runway. It is a voice pilots are trained to trust; "radar contact" is a phrase that gives one a sense of security. One understands that he is getting descent clearances "as traffic permits." Even the FAA regional director confirmed that, in his opinion, 99 percent of pilots would have taken the controller's instruction without question. [369] A descent clearance to 5000 (at the appropriate time) was *expected* by the MAC crew as part of the normal vectored approach pattern. A few moments later, the "maintain 5000" clearance would have been entirely appropriate. In the continental U.S., clearances are not interpreted as "descend to such-and-such altitude *at your own risk*," although clearly that is the case, even if the risk is small.[93] The FAA might wish to contend, perhaps, that clearances should be interpreted as "descend to such-and-such altitude *at pilot's discretion*." But then you can't have a sky full of airplanes with everyone using their own discretionary option to delay the execution of the clearance. The thing that makes the whole complicated system work is that "controllers" are in "control." That's why we call it "controlled" airspace -- there are rules that must be followed and one of them is to follow the controller's clearance.

In terms of accident prevention, obviously it is prudent for the crew to be simultaneously cognizant of its aircraft status (position, heading, speed, altitude, rate of descent, fuel, etc., etc.), its environmental conditions and constraints (weather, terrain, other traffic, etc.), its intentions and the intentions of ATC through the flight plan, current clearances, and so forth. Had the crew questioned the clearance or delayed its implementation, this tragedy could have been prevented. Undoubtedly, the Safety Investigation Board had recommendations that would enhance these factors through training, terrain charts for pilots, etc.

In terms of an apodeictic explanation of this accident, however, the Safety Board's analysis of the facts focuses a considerable amount of culpa on the FAA. The facts undeniably indicate that the accident was caused by an erroneous clearance given by a journeyman qualified FAA controller who was not following prescribed

93 Flights in South America, for example, are another matter. Full radar coverage does not exist and clearances are intended to refer to other en route air traffic *only*. They may take a pilot inexperienced in the Southern hemisphere into a mountain.

procedures of operation. The aircrew simply followed the controller's directives which took them below the minimum clearance altitude for their flight path, resulting in a collision with the face of a mountain, destroying the aircraft and killing all aboard.

Addendum to Chapter 7:

MAC 40641 Rescue and Recovery Effort

The Air Force description of the rescue effort comes from the AFR 127-4 Safety Investigation Report, Part I. Not evident in this Air Force report were the initial ground coordination problems that accompanied the rapid response by several agencies. A thorough documentation of the ground rescue effort is included here for a complete perspective, as well as for other important lessons that can be learned from MAC 40641. The source of this information is Park Service Incident #8800 Reports (3/31/75, 4/6/75, 4/9/75, 4/12/75, 12/3/75) and personal notes from George Bowen, Supervisory Park Ranger and manager of the Hoodsport Unit of Olympic National Park. Mr. Bowen, who was a central figure in the ground effort, gave a presentation to the Air Force Inspection and Safety Center (AFISC) at Norton AFB, CA, on this accident and what was learned that could benefit mishap investigators and future rescue and recovery efforts in times characterized by extreme confusion, frustration and exhaustion.

Rescue Effort

The mobilization of emergency rescue personnel was rapid, but coordination was hampered by, among other things, uncertainty of the location of the aircraft near the Park boundary, an uncertainty that lasted for several hours. The incident rapidly (within 2 or 3 hours) involved at least nine government agencies (and 13 different organizational units) at the Federal, State, and local County levels, and three chapters of a volunteer organization among which coordination of the ground effort had to be organized: FAA (Seattle Center), USAF (McChord, McClellan, and Scott AFBs), US Army (Fort Lewis), US Coast Guard (Port Angeles), Washington State Department of Emergency Services (DES), National Park Service (Hoodsport District of Olympia NP, Seattle Regional and Washington National Offices), US Forest Service (Quilcene Ranger District, Olympic NF), Mason County Sheriff Department, Jefferson County Sheriff Department, and the Mountain Rescue Association (MRA - Seattle, Tacoma and Olympia Chapters). The effort to rescue any survivors would be dedicated, valiant and confused.

Seattle ARTCC at Auburn, WA, alerted the Washington State Department of Emergency Services (DES), who alerted the Hoodsport Unit Manager for Olympic National Park, George Bowen, at 0045L, along with the Mason County Sheriff Office. The location was tentatively placed at either Mt. Constance or Mt. Deception; both are in the Park but about 6 miles apart. The peak of Mt. Constance is less than 1/4 mile within the Park boundary. The Coast Guard alerted the Park at 0050L that the aircraft was down on Mt. Constance and launched a helicopter for the first search and rescue (SAR) effort; but, they were unable to reach the vicinity due to weather (heavy snow showers). At 0115L, Park personnel were contacted by Army WO Ed Cleeves from Fort Lewis, who stated he is the Operations Leader for the search and rescue (SAR) effort and that the crash location is at Mt. Deception, elevation 7500 feet. The Air Force HC-130 that departed from the San Francisco area was to be over site by 0230L to locate the Emergency Location Transmitter (ELT). At this time Cleeves moved his Operations Center from Fort Lewis to Payne Field, Everett, WA.

At 0219L Washington State DES advised Olympic Park that 33 Mountain Rescue Association personnel (10 from MRA Seattle, 10 MRA Tacoma, 8 MRA Olympia) are being sent; but to where? The weather was a big factor in the ground effort as well as the air effort. Heavy snow was falling as low as the 500 foot elevation. Travel on logging roads was impossible. At 0315L the Park Unit Manager and Mason County Sheriff Deputy reported negative results in reaching trailheads by vehicle. At 0430L the Park was notified by Ed Cleeves of the Army that the search area, based on the latest ELT signal location by the HC-130, was now determined to be Marmot Pass by Buckhorn Mountain, outside Olympic Park and in Jefferson County. (The HC-130, dealing with poor weather conditions, had to maintain 30,000 feet altitude, resulting in imprecise ELT readings.) Forest Service Ranger Pat Hanna from the Quilcene Ranger District, and Jefferson County Sheriff Office were called and advised of the new location. With the accident no longer determined to be on National Park property, the Park put Cleeves and Jefferson County Sheriff in touch with each other at 0440L and the Park Ranger team that was put on standby at 0250L, now stands down.

At 0515L the Park was called by the Col Hemjum of the SAR center (Western Air Reserve, Aerospace Rescue and Recovery Service) at Scott AFB, IL; Park advised Col Hemjum of details of operation and the last location of the ELT signal. At 0530L the Park advised the Pacific Northwest Region Office and the Washington Supervisor's Office of the National Park Service (WASO was originally notified of the incident at 0215L and had assigned the Olympic Unit an incident reporting number #8800) that the crash location was outside the Park. Park personnel returned home about 0610L.

Less than two hours later at 0805L, the Park was notified by the Regional Office in Seattle that they had received word the crash was indeed inside the Park and wondered what action was being taken. The Park Dispatcher's information at this point was still unchanged -- that the crash location was fixed on Buckhorn Mountain outside the Park. At 0810L Pat Hanna of the Forest Service advised the Park that the *new* location is on the west side of Mt. Warrior (inside the Park) at 6800 feet. Scott and McChord AFBs had turned operation over to Washington State DES. The ground leader was now Glenn Kelsey, a volunteer with the Mountain Rescue Association; with Bill Booth, Jefferson County Sheriff, and US Forest Service assisting. At 0940L the State DES calls Park and confirms that the *new* crash location is now inside the Park. Park crews are placed on standby again and the Park advises Regional and Washington Offices of new location inside Park.

At 1114L the Park and Forest Service jointly decide through a conference call that, due to the imprecise ELT readings, no one will commit teams until they get a verified location. Leadership of operation is to remain the same until further notice, even though the crash is now thought to be in the Park. By 1208L the Operations Center had been moved from Payne Field to Quilcene Ranger Station (Forest Service). Weather still prevents any prolonged search by helicopter. By 1225L Park Rangers were discovering that winter rescue equipment was scattered all over the Park. The main cache at Elwha Ranger Station could not be entered for tents and radios due to bastard locks to prevent theft (the Ranger was then ordered to cut the padlocks).

Jack Hughes, Park Snow Ranger who was requested by DES to provide expertise on avalanche control, and George Bowen, along with Mountain Rescue personnel, were to be flown to within three miles of the site by 1330L and spend the night on the mountain. The wreckage had been spotted by a USCG helicopter, but they were unsure of its exact location and thus would lead in the Army helicopter which contained the ground rescue crew. The flight was aborted at 1246L due to weather; they could not land but did accomplish a fly-over of the crash vicinity. A US Forest Service observer says the wreck is definitely in the Park, but not sure of exact location. The Coast Guard says the wreckage has *not* actually been sighted but they feel sure the wreck is in the Home Lake vicinity (headwaters of Dungeness River); Park Snow Ranger Hughes agrees.

At 1355L Hughes advised Park Headquarters that Operations Center is going to be moved again from the Forest Service Quilcene Ranger Station to the Coast Guard Air Base at Port Angeles; requests that the Park Service crew be held in Port Angeles until further notice. At 1450L Assistant Chief Park Ranger Tony Anderson contacted Col Hemjum at Scott AFB and advised him of the necessity of having a Park representative involved in the operation. Hemjum advised Anderson that the Operations Center would remain at Quilcene and that the Park should route additional personnel and equipment to same location. Oversnow machines were en route. At 1515L a lowboy tractor/trailer with 15 snowmobiles arrived at Quilcene Ranger Station and at 1600L the Park Ranger Team was dispatched to Quilcene. At 1610L a decision by concensus, supported by Col Duncan, the "Crash Commander" at McChord AFB, was made to move Operations Center to the Coast Guard Base at Port Angeles. All personnel departed Quilcene at 1630L. The Quilcene office closes for the night which creates untold confusion for parties calling in from various agencies.

A three hour "Let's get organized" meeting was conducted at Park Headquarters from 2100L to 2355L with all parties concerned, including Andersen, MRA member and Ranger team to discuss SAR problems and plans. The Park will lead all ground effort. Col Duncan, USAF McChord, will provide all military liaison. Ed Cleeves, Army, will coordinate all helicopter support. The first 24 hours since the crash ends with everyone totally exhausted and only one concrete bit of information -- the crash is inside the Park.

The next day, Saturday, 22 March, three sorties are flown with the assistance of HC-130 flying "Cap-Com," Army and Coast Guard helicopters. All operations, planning, logistics, and transportation originate from the Coast Guard Base at Port Angeles. The site is positively identified on the northwest face of Inner Constance above Home Lake. Experienced Park personnel observe that in addition to approximately one foot of fesh snow, it is evident from lack of visible wreckage that the aircraft was covered by avalanche immediately after impact. Limited numbers of the most experienced Mountain Rescue and Park personnel are inserted into the crash scene. Another weather disturbance was due during the day. Personnel were equiped to spend the night as the first priority was to determine signs of life. The Air Force Investigation Board members examined the wreckage from the air.

Daily flights were made into the scene between weather fronts. The first body was found on 25 March; no others were to be found until 25 May. Due to continual unsettled weather conditions, the depth of snow, and inaccessibility, the decision was made to postpone any further search efforts until the snow melted and avalanche runs ceased. Both the Air Force and Park were concerned about public encroachment into the area. Legal notices were signed, published and posted closing the area.

Recovery Effort

Overflights by Park and Air Force personnel were made weekly to monitor melting and signs of unauthorized persons entering area. April 6th flight report states that only the tip of the tail section was visible now due to more snow and avalanche. April 9th flight reports ski tracks observed five miles north of scene. This proved to be the closest intrusion. As the spring progressed the jet fuel stain on the snow proved to be an excellent indicator that snow had melted back to the depth when the crash occurred.

Poor weather prevented the establishment of a permanent camp until 9 May 1975. On that date Olympic National Park rangers, under the direction of George Bowen, Supervisory Park Ranger, Hoodsport Subdistrict, established a base camp mainly for surveillance and security at the site until the site could be explored free of avalanches. As conditions permitted, the objectives included the location and recovery of bodies and the flight data recorder.

May 9th became the date for the recovery phase of operation and a base camp was established 100 yards east of Home Lake. Facilities were set up for a combined team of Air Force Para-Jumpers (PJs) and Park Rangers. The objective was to provide security for the area, locate and recover bodies and flight recorder. Weather prevented teams from leaving the camp on occasion. The camp maintained continual communication with McChord AFB, Coast Guard Port Angeles, and Park

Headquarters. Melt rate increased rapidly from May 15 and the wreckage and bodies began to melt out of the snow. Bodies were easy to work with since they had been frozen since March 20.

The melt rate increased rapidly after 15 May and the first body was exposed from the snow melt on 17 May; the body was that of crew member A1C Robert Gaskin. However, it was not until 27 May that conditions were suitable for full-scale recovery efforts to begin. On 28 May, the remains of two passengers were recovered, PO3 John Eves and Lt Edward Uptegrove. The next day, 29 May, two more bodies were found, those of crew members TSgt James Campton and SSgt Peter Arnold. The Safety Investigation Board reconvened on 2 June to take charge of the on-site recovery. On 2 June, passenger WO3 Samuel Fleming was located and recovered. On 5 June, passenger PO3 Jeffery Howard was recovered and passenger SM (Signalman) Donald Deckson was recovered the next day. The bodies of three crew members, Lt Earl Evans, Lt Col Ralph Burns, and Capt Frank Eve, were recovered on 10 June, and that of crew member 2Lt Harold Arensman the next day. Recovery of human remains was completed on 14 June with the discovery of the last three bodies, 1Lt Stanley Lee, MSgt Robert McGarry, and passenger PO3 William Raymond.

The bodies were found in frozen condition and were transported to Madigan Army Hospital at Fort Lewis, WA, near McChord AFB, for identification. Identification required from one to several days, depending on the condition of the remains.

Another phase of the operation was to investigate the impact site. This required flying to the ridge and climbing down to the cockpit location. The impact point was identified and it became poigniantly clear that only another 200 feet of altitude would have brought the plane safely over the ridge -- the equivalent of a 10 second delay in executing their descent.[94] The cockpit flight data recorder was recovered 12 June. The final phase was to remove wreckage. By June 14 all bodies were accounted for and the flight recorder was recovered. The last phase of removing the wreckage was pursued daily as weather permitted. Army Infantry were flown into the site daily and loaded large containers by hand. Engine pods, wheel assemblies, and tail were sling loaded under Chinook helicopters and flown to the Coast Guard Air Base at Port

94 The end would still have been tragic, however, as the plane would then have struck *The Brothers* mountain seven miles further down course after having leveled off at the 5000 foot level. The Brother peak rises to 6866 feet.

Angeles. The cockpit was imbedded in rocks and crevices and had to be blasted off the mountain face. By September 1975, the operation was considered complete. On September 1, 1975, the crash site was reopened to the public. Approximately 99% of the wreckage had been removed from the Park and all sensitive items were recovered.

The cost to discover, recover and remove the aircraft and remains was $684,000. [370]

Estimated costs for the recovery were:
NPS: 2044 hrs reg. time, 250 hrs OT, for $4,268 (non-programmed)
Military: 23,100 hrs, for $600,000
Volunteer: 4,000 hrs, for $80,000 (uncompensated cost)

Total: 29,394 hours, $684,268 (not including fuel and equipment costs)

Chapter 9

A Paradigmatic Explanation of the MAC 40641 Accident: Understanding the Context

In previous chapters I have chosen to focus my discussion around four broad and general paradigms in an attempt to ferret out contextual aspects of aviation safety for our examination and understanding. The structure of this background development, however, is not necessarily the most natural way to examine the context of a specific phenomenon such as the 40641 accident. Therefore, we will structure our understanding of contextual aspects of this accident in a way that most naturally adapts to this event. Although not all aspects discussed in the paradigms developed earlier are applicable here, MAC Flight 40641 is a paradigm of the context of aviation safety in that it is a concrete example that exhibits these broad contextual patterns quite well. These will be pointed up as we proceed with our paradeictic explanation.

The source of information used in this section and its interpretation comes from a combination of publically available information (sworn testimony and news media interviews), my personal interviews and discussions with C-141 McChord crew members familiar with both the accident and MAC operating policies, discussions with others who have knowledge of this event, and my own personal experience as a former C-141 navigator stationed at McChord AFB. The publicly available information includes some intensive investigative reporting, the results of which were published in the time period of the accident. This investigative journalism provides an inside "unofficial" perspective, as presented by events which unfolded following the accident and stories which were conveyed by many C-141 crew members; for convenience I cite here the entire collection of articles that could be located regarding this accident. [371] I will also draw extensively from the publically available sworn statements and testimony given to the USAF Investigating Officer in the Collateral Accident Investigation by 51 witnesses, cited here. [372]

I will begin by focusing on contextual aspects of the flight itself and then expand out to the broader context within which this flight occurred. There is no clear dividing line nor is this an intendedly linear presentation as most of these contextual factors interact in some fashion or another. The issues more directly associated with the flight and the accident are the cognitive frameworks of the controller and the crew, the relevance of fatigue, and decisions made by the aircraft commander.

MAC can be viewed as a technological device which procures rapid transportation for military materiel and people. It suffers the same paradigmatic pressures for availability as any other device. Safety will be seen as blantantly obsequious to the more tangibly experienced aspects of availability -- ubiquity and instantaneity of the commodity rapid transportation -- and these are supported by the technological expectations of efficiency and so forth. The broader issues encompass the safety climate and its erosion, policy decisions, and distortion of information through adaptive avoidance of disruption on a broad scale. Finally, the summary will complete the case for explaining and understanding this mishap as a "normal" system accident. Technological issues will be pointed up where appropriate.

Cognitive Framework of the Controllers

In earlier chapters (1 and 3), we have alluded to the communications context of the slip by the controller in giving the 5000 foot clearance intended for the Navy flight, to the MAC flight. Both were descending to 10,000 feet under Sector 3's (referred to subsequently as D3) control; MAC 40641 called level at 10 and was immediately cleared to continue on to 5000. D3 never intended the clearance to be for the MAC plane; D3 was in the midst of preparing to give that clearance to Navy 28323 when the MAC plane called in and he was never cognizant of the slip until an hour later when the tape was reviewed. The following exerpts from statements of the three controllers who were involved provide additional insight from their perspectives.[95] Due to light traffic at the late hour, the controller for Sector 3 actually was operating two positions combined, the Radar position, R3, and the Data position, D3. The Radar Controller monitors the radar screen and the Data Controller assists him or her by updating the Flight Strip Data containing clearances among other things. Sector 2 Radar was monitoring the MAC flight in preparation to receive him in the handoff from 3. Data Controller D2 was also monitoring the MAC flight.

95 These were written statements on FAA letter head. It doesn't appear that the controllers underwent direct questioning or gave any verbal testimony to the Collateral Investigator.

Statement of Sector 3 Controller, R3/D3 (abridged): During the period 2231 GMT on March 20, 1975, to 0700 GMT, March 21, 1975, I was on duty in the Seattle Center. I was working positions R3 and D3 combined from 0533 GMT to 0607 GMT. At approximately 0540 GMT, I relieved the radar controller on Sector 3 and 33. Traffic was light to moderate. At approximately 0545 GMT, Vancouver Centre effected a radar handoff of M40641.

[After some initial radio communication difficulties], at approximately 0548 GMT, I contacted M40641 on 121.5/243.0 (the guard frequency) and requested M40641 to ident as an acknowledgement of reception of the transmission. I verified his acknowledgement by observing his ident feature on the radar scope. At approximately 0548 GMT, two-way communications were established on 121.2. Shortly thereafter, I assigned M40641 a heading of 160° to vector the aircraft west of Seattle Approach Control's airspace in anticipation of a precision approach runway one six at McChord AFB. At that time (approximately 0548 GMT), I cleared M40641 to descend and maintain 17,000. This provided separation from CFJLJ northbound at 16,000 to Vancouver, B.C.

At approximately 0550 GMT, I received a radar handoff from Sector 1 on VV28323. The Navy aircraft was en route from Boardman, Oregon, to Whidbey Island Naval Air Station and his assigned altitude was flight level 220. I established radio communications with VV28323 shortly thereafter.

At approximately 0551 GMT, I received two estimates from Vancouver Centre on Alaska 96 and Western 720, both landing at Seattle. At approximately 0552 GMT, M40641 advised level at 17,000. I observed M40641 to be past CFJLJ and descended M40641 to 10,000; at the same time, I assigned M40641 a heading of 150°. I planned to effect a radar handoff of M40641 to Sector 2 in approximately ten miles[96].

At approximately 0553 GMT, I assigned VV28323 a heading of 310° and told the aircraft to expect runway one three at Whidbey Island for landing. Shortly thereafter, I cleared VV28323 to 10,000. the aircraft acknowledged the clearance.

At approximately 0553 GMT, I received a radar handoff on Northwest 26 inbound to Seattle. At approximately 0558 GMT, I effected a radar handoff to Vancouver Approach Control on CFJLJ and shortly thereafter advised CFJLJ to change to Vancouver Approach Control's frequency. At approximately 0554 GMT, I assigned NW 26 a heading of 120° for runway one six at Seattle.

At approximately 0556 GMT, M40641 reported level at 10,000.[97] At that time, I was reviewing the minimum vectoring altitude chart in anticipation of descending VV28323 to a lower altitude. After assuring myself that the radar target of VV28323 was in the lower MVA altitude area, I then issued the clearance.

At approximately 0558 GMT, VV28323 reported level at 10,000.[98] I questioned VV28323's altitude and asked if the aircraft was level at 5,000. Upon receiving a negative reply, I cleared VV28323 to 5,000. I believed, at that time, VV28323 had received my initial clearance but had not acted upon it. At approximately 0559 GMT, I effected a radar handoff of VV28323 to Whidbey Approach Control; shortly thereafter, I instructed VV28323 to contact Whidbey Approach Control.

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96 My note: at 250 to 300 knots ground speed, that would be two to two and a half minutes. The exact time of 40641's acknowledgement was 0552:28; which would have meant an intended handoff at about 0555.

97 My note: Exact time was 0556:16. D3 responded with the 5000 clearance at 0556:19; MAC acknowledged at 0556:25.

98 My note: Exact time V28323 reported level 10,000 was 0558:35.

At approximately 0600 GMT, I was vectoring NW 26 and observing a target northbound from Seattle Approach's airspace whom I believe to be Saturn 10. I had been told by Seattle Approach the aircraft would be on course V440 and noted the target was passing *through* [my emphasis] the on course radial and proceeding northbound toward NW 26.[99] Shortly thereafter, Sector 2 requested the location of M40641.[100] I looked to the western edge of my radar display and could not locate the aircraft. I attempted to contact M40641 without success. Sector 2 informed me he had lost radar contact with the target he believed to be M40641 in the vicinity of Mt. Deception. It was at that same moment, approximately 0601 GMT, that I stated to Sector 2 the concern that M40641 may have mistakenly accepted VV28323's clearance to 5,000. I believed this to be the situation up to the moment I heard the tape recording.

Equipment status: radio frequencies normal, broadband radar normal, narrowband not available. [373]

Statement of Sector 2 Radar Controller, R2 (abridged): During the period 2250 GMT, March 20, 1975, to 0731 GMT, March 21, 1975, I was on duty in the Seattle Center. I was working position R2, Sectors 1, 2 and 32 combined, from 0534 GMT to 0639 GMT. I signed on the R2 position at approximately 0534 GMT. I was properly briefed by the controller I relieved.

I was informed by the D2 controller at approximately 0550 GMT that M40641 was at the Discovery Intersection. At that time, I observed and radar monitored the aircraft from the Discovery Intersection area as it proceeded southbound toward my sector.

At approximately 0600 GMT, I observed the target merge with the video display symbol of Mt. Deception on the Sector 2 radar map. The target appeared to merge with the northeast corner of the Mt. Deception video marking. After M40641's transponder target disappeared, I turned the MTI gain up trying to pick up a primary target. There was neither a primary or a secondary target. The D2 controller and myself both asked the Sector 3 controller where the M40641 was at. The Sector 3 controller said he last observed the aircraft on a radar vector heading southbound in the area of the Bremerton Intersection.

At approximately 0602 GMT, I had NASA 714, another aircraft I was working on my frequency, call M40641. Because D3 controller expressed some concern to me that M40641 may have accepted VV28323's clearance, I requested NASA 714 to instruct M40641 to climb to 10,000 feet.

At approximately 0604 GMT, Sector 3 was combined on Sector 2. At that time, Sector 3 had three or four aircraft. NASA 714 attempted to establish radio communications with the MAC, but was unsuccessful. I also tried to contact the MAC through the emergency channel, also with no positive results. I then asked NASA 714 to monitor the emergency frequency for a possible emergency locator transmitter. NASA 714 stated he was picking up a weak ELT onn his UHF emergency frequency. I asked NASA 714 if he had airborne DF equipment on board but he advised he was not so equipped. I asked RINE 95, another aircraft on frequency, if he was DF equipped. He stated he was. At approximately 0609 GMT, I asked RINE 95 if he would accept a radar vector toward the last observed position of MAC aircraft. He accepted the vector. At approximately 0614 GMT, RINE 95 received a DF fix on the ELT. At approximately 0615 GMT, RINE 95 indicated he had received a needle swing indicating he had passed over the ELT. I observed this position to be about the same as the last observed radar position of the MAC flight. This position was about forty northwest of the Seattle VORTAC.

Supervisors were given all this information. I was relieved from the R2 position at approximately 0639 GMT. [374]

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99 My note: D3 cleared NW 26 to 9000 at 0556:48 and at 0556:58 was told by Seattle Tower that Saturn 10 was off of Boeing at 0554. At 0558:47 Seattle Tower requested an approval for "on course Saturn 10," which D3 approved.

100 My note: Exact time was 0600:04.

Statement of Sector 2 Data Controller, D2 (abridged): During the period 2230 GMT, March 20, 1975, to 0700 GMT, March 21, 1975, I was on duty in the Seattle Center. I was working position D2, combined Sectors 1, 2, and 32, from 0549 GMT to 0634 GMT.

I observed, at approximately 0550 GMT, that M40641 was ten minutes overdue at the coordination fix. I called over to the D3 controller to find out where the MAC flight was. The D3 controller advised me that the flight was still up north at Discovery Intersection and that he was having radio problems with him. I pointed the target out to the R2 controller and we both continued to radar monitor the flight. I expected that the MAC flight would be put on a radar vector west of V287 with an en route descent. At this time, we had approximately six to seven aircraft on frequency.

At approximately 0600 GMT, I observed that the target of M40641 had disappeared in the vicinity of Mt. Deception. I immediately called D3 to ask where the MAC flight was. I then called Seattle Tower and asked if they could see any radar targets west or northwest of Lofall Intersection; they said no. I heard both R2 and D3 controllers attempting to contact the MAC on emergency frequency and by relays through other aircraft. I then called the Watch Supervisor and asked for a supervisor to come down to Area A1. I then called McChord Approach Control and advised them that M40641 was overdue and believed to be down. At this time, we combined Sector 3 with Sector 2.

I then called Whidbey Approach Control to see if they had any aircraft in the air for a search and rescue. They advised they had a P2 (VPJ12) in the pattern with DF and four hours fuel remaining. I issued a clearance to Whidbey Approach for VPJ12 for 10,000, heading 190. R2 advised me RINE 95 heard the emergency locator beacon and got a good swing on the DF needle overheading Mt. Deception. I advised the Watch Supervisor of this. I was relieved of my position at approximately 0635 GMT. [375]

Statement of Area A Team Supervisor (abridged): [After I was briefed by the Sector 3 controller] I asked the Sector 3 controller if he had asked other aircraft to attempt communications with the MAC flight. He advised attempts had been made but were unsuccessful. The Sector 3 controller stated that he had issued a descent clearance to 5,000 feet to a Navy aircraft inbound to Whidbey Island and that he thought MAC 40641 may have copied the descent clearance. I took steps to relieve the Sector 3 controller from controller duty pending further review. [376]

Two things are evident. First, controller D3 succumbed subconsciously to a mental slip, the context of which was his temporary preoccupation with the examination of terrain clearance charts for another flight. It was not a conscious error as would be the case, for example, if the clearance was intendedly and knowingly, but improperly, given to the MAC flight without first checking for location and terrain clearance. D3 *was* conscientiously checking terrain in preparation for a clearance to 5000 feet. D3 had intended not to *descend* the MAC flight but to *hand him off* to R2 cleared to 10,000 feet. For what ever reason, the MAC flight had momentarily left his conscious mind; D3 was preparing to clear V28323 to 5000, but also had intended to hand off MAC 40641 at about the same time the MAC plane happened to call in level at ten. He gave the clearance to the MAC flight instead of handing him off to R2; he remembered giving the clearance to the Navy plane and "forgetting" to hand off the MAC plane. So complete was the slip that even the Navy flight calling level at ten when D3 thought he should already be at five, having (he thought) given him that clearance, did not trigger to his consciousness that he had not yet handed off MAC 40641.

The key point here is that these kind of mental slips happen to human beings all the time, as we discussed in Chapter 3, and we can expect them to happen over and over again. We will always be human. It is a tragic fluke that it happened in just the right combination of circumstances that resulted in this accident. I can tell you from 2500 hours of experience in the air that controllers, just like aircrews and anyone else, make mistakes. Most of the time they are caught or do not constitute an immediate hazard. If the 40641 pilot had responded: "Ah, Seattle 40641, is that 5000 for us?", there likely would have been no accident. The controller would have come back with something like: "Negative 641, maintain ten thousand; Navy 28323 cleared to five thousand." He wouldn't have said; "Woops, sorry 641, that was intended for 28323," because he was convinced he gave it to 28323 in the first place. Unfortunately, these kinds of communication errors do take place. Now, the situation would then properly have called for the crew, after they landed, to write up and submit an OHR, or Operational Hazardous Report, on the controller for almost clearing them to descend into the mountains. But it is doubtful they would have even done that, and I'll discuss that in much more detail later.

The second thing worth commenting on is in regard to the equipment status. D3's written statement referred to "broadband radar normal, narrowband not available;" but, there was no explicit reference to inappropriate PVD procedures for broadband, e.g. vertical mode instead of horizontal, nor to the tracking of flight information on "shrimp boats." Secondly, we know that clearances were recorded on the flight data strips; the 5000 clearance given to the MAC plane was recorded on the Navy 28323 strip, not the MAC 40641 strip. Thus Sector 2, who would pick up the latest clearance information from the flight data strip on the MAC plane he was receiving, could not know a slip was made, even though two additional controllers, R2 and D2, were closely monitoring the flight path of MAC 40641 in anticipation of a handoff. Recall, they only had transponder Mode 3A data, which does not decode altitude. Had narrowband radar been in use, such a slip would have been observable on their screen through the Mode 3C altitude encoded information tagged with the radar target. R2 or D2, or even D3, would likely have spotted altitude changes even if no one was aware of the clearance slip. This indicates the potential safety impact of maintenance scheduling policies.[101] More on that later.

Cognitive Framework of the Crew

We will examine the crew's acceptance of the descent clearance from two contexts. One explains why the crew should have caught the wrong clearance and the other why they did not.

Why the wrong clearance *should have been* caught:

Possible mistakes by controllers are not consciously ignored by flying professionals such as those in the Air Force. So important is the crew's cognitive framework or mental set during descent and approach phases of flight, that specific regulations and procedures are designed to ensure that all of the crew is functioning within the same framework for safe and proper execution of this portion of the flight. Crew duties are specifically spelled out and the descent and approach checklists call for a crew briefing for each of these phases. The pertinent aspects are summarized in the discussion section of the Accident Investigation Report.

> The C-141 flight handbook (T.O. 1C-141A-1, page 2-51)[102] requires that a descent briefing be given in conjunction with accomplishing the "descent checklist." It specifically requires the pilot to brief "...significant arrival restrictions to include minimum sector altitudes and terrain/obstacle hazards" (Tab EEE). Further, MAC Regulation 55-1 and MAC Supplement 1 to AFR 60-16 state, "...Prior to descent from cruise altitude, the pilot will brief on (and insure the crew understands) the applicable minimum altitude/terrain clearance requirements for the expected route of flight, the minimum safe altitude (minimum sector/emergency safe altitudes, as applicable) and the significant terrain/obstacle hazards in the terminal area. During descent, the pilot will insure that the altitude he accepts will provide adequate terrain clearance. The copilot and navigator (if applicable) will assist the pilot by referring to appropriate FLIP (flight information publications) documents and maps/charts." (See MACR 55-1, ¶ 4-5d, and AFR 60-16/MACSUP 1, ¶ 8-15a) (Tab EEE).

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101 As an aside, it is appropriate to comment here that this is an obvious opportunity for a technological aid. In fact, it could be easily programmed to flash, or encode in a different color, for example, the altitude of any target for which the altitude was changing. At the time of this accident, color screens obviously were not available; any flagging method could have helped, but most importantly, the computer processed radar was not available due to management decisions.

102 This important document, which is sort of an "operator's manual" for the C-141A, is commonly referred to as the "dash one."

> Sequentially following this "descent briefing," MACR 55-1, ¶ 4-5e, further requires an "approach briefing" which covers the pilot's intentions during the approach and landing phase. It is significant to note that, again, the pilot is required to brief his crew on "...minimum sector altitude and terrain/obstacle hazards..." (Tab EEE).

These regulations and procedures are reinforced through crew training, both in the simulator (for pilots) and in the air, and are explicit items covered in flight evaluations or "check rides." In testimony from the officer in charge of the Flight Simulator Section and from the Flight Simulation Instructor who most recently conducted simulator training and evaluations for the aircraft commander (AC), 1Lt Evans, it was stated that erroneous descent clearances are specifically simulated to see if pilots respond to an unsafe clearance. Although the simulation is not specifically for the McChord approach over the Olympics, it involves several terrain clearance problems in which clearances are given at some point during the simulation ride that would put them into terrain difficulties if they accepted the clearance. At least one is under radar contact with an intentional clearance to an altitude which is lower than what they should accept while not under radar contact. The testimony of these flight simulation people indicates that Lt Evans was very astute and quite competent. He immediately caught the faulty clearance and told his copilot to inform the controller, "No, tell them we can't go that low, the minimum en route altitude here is higher than that, we will maintain the minimum route altitude."

Testimony by Wing and Squadron Flight Standardization and Evaluation Officers[103] indicate rigorous emphasis on this in flight training and evaluation. Witnesses were selected who had personally flown with the 40641 crew members. All crew members were described in one fashion or another as "very thorough" (i.e. in briefings) and "very professional in their approach to flying." There was no one who would believe for a second that the descent or approach briefing, for example, would have been ignored, skipped over lightly, or forgotten by anyone in this crew. You had, in this case, five crew members in the cockpit at their stations performing their respective duties. Things like skipping the descent or approach briefings just don't happen. They are on the checklist of each individual crew member.

Captain Eve, the augmenting pilot who was sitting just behind the radio console between the two pilots in the flight examiner "jump seat" at the time of the crash, was considered ready to upgrade to instructor pilot and was being planned in to the

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103 These are the people, referred to collectively as "stand-eval," who set and enforce the rules.

upgrade program. One Operations Officer, a Major, commented about Eve: "I don't think I have flown with a more careful or conscientious aircraft commander." Another pilot who had flown with Eve commented in response to a question as to whether or not Eve would be reluctant to speak up or speak his mind to the AC, saying: "I feel he would speak up. He was that type of individual, he was a safe individual. Just from flying with him, [I know] he didn't take chances."

Lt Evans, flying the left seat, had had six or seven check rides in the last five months in conjunction with his recent upgrade to aircraft commander in December 1974. His performance was considered very solid throughout. The flight examiner who gave him his line evaluation for AC described him as "above average." The feeling of the officers who officiate the standardization and evaluation duties of the Wing and Squadron is that once a pilot reaches the point where he is entered in the rigorous AC upgrade program and successfully accomplishes the AC upgrade, he is a fully and well qualified pilot. In fact, one stated that MAC pilots, as a group, are probably the strongest qualified pilots in the world because of the strict training and procedures, and the processes they have to go through to develop their experience.

Testimony also indicated that flight crews should even have increased awareness of terrain because of recent accidents that occurred in MAC within the last year and a half. Not only is terrain avoidance and assurance of terrain highly stressed in upgrade programs, there had been several written publications coming out stressing terrain avoidance, making sure of your position. "In other words," one individual stated, "it is evaluated on all flight evaluations and is well known by all pilots and navigators that it is a stress fact and something to be very cautious of."

During the descent and approach phase of the flight the navigator is no longer needed to position the aircraft since the flight is on airways or under radar contact. This frees the navigator to perform his *only* responsibility during this phase -- that of monitoring the position of the aircraft, terrain, and clearances.[104] Failure to do this during a flight evaluation would result in failing the eval and becoming unqualified -- a matter of serious concern for the individual crew member and his commanding officer. In fact, approach and departure monitoring, and terrain avoidance, it was

104 So engrained had this safety routine become for myself while I was in the Air Force, that I found for quite some time after I got out that I was very uncomfortable on commercial airline flights because I could not be "on headset" monitoring what was going on. Were the pilots getting and following the right clearances? It bothered me a great deal not to be a part of that process.

testified, have always been on the monthly Flight Crew Bulletins, which are a list of special emphasis items for 62 MAW Flight Examiners -- pilots and navs. There are no exceptions, even under radar contact. I can tell you from my own expeience that not only would a conscientious navigator do this regularly as part of his routine, but if there were another navigator on board, for whatever reason, the implicit peer pressure and professional pride would be additional factors encouraging you not to slack off at this point of the flight. And if that additional navigator was an instructor or flight examiner, even if you were not in a training or evaluation situation, and even if he was not on official flight duty (i.e. just "deadheading"), you would endeavor to exhibit the utmost professionalism and do things "per the book." And if you, as the navigator on duty, were one of these training or evaluation people yourself, not only would you want not to be hypocritical by slacking off, you would want to set the best professional example you could for the younger members of the crew. Crew members and Air Force officers in general take a great deal of pride in their professionalism.

Ironically, this plane carried a complement of three fully qualified, competent and proficient navigators. One, 1Lt Lee, was a line qualified navigator. Lt Col Thornton, who was at the navigator station, was the Wing Training Officer at McChord (the chief of the 62 MAW training division) and he had a total flying time of about 3330 hours. Lt Col Burns, a Flight Examiner Navigator, was the Wing Standardization and Evaluation Navigator with about 7550 hours of flying time. Testimony by Flight Standardization officers and Flight Examiners who worked closely with both Col Thornton and Col Burns had very positive comments about both men.

Col Thornton was described as a "super-conscientous guy." He was deeply involved with training and standardization; of which, approach procedures for the navigator were a very important part. In fact, Col Thornton was the project officer for a new training program called TERPS, Terminal Instrument Approach Procedures, to be required of all navigators, as well as pilots, in which such things as approach plates, descent procedures and terrain avoidance were discussed. This was a program designed as a refresher course by Col Burns, whom Thornton worked closely with in his Wing staff position, and 92% of the squadron navigators (including Col Thornton and Lt Lee) had completed the course recently. In fact, the course was so good that its reputation extended beyond the 62nd Wing at McChord; people from higher headquarters were calling saying they heard that McChord had the best TERPS program in MAC and that they wanted to use it at other MAC bases.

Col Burns was touted as probably the best navigator at McChord and a "super-professional Flight Examiner, a guy you looked up to." He was "an extremely precise individual, very intelligent, well respected." Another observed him to be "probably one of the most capable men I have ever met in the Air Force -- very conscientious, very thorough and extremely capable." A person who knew him well stated:

> He impressed me as the most complete standardization Navigator I every knew, ever worked with. I used him as the example, that you couldn't do any better than what he was doing, not only working in the office with him on these projects, but in flight.
>
> I went over this very area [Olympic Mountains] the month before [the accident] with Col Burns looking over my shoulder administering my annual evaluation. To me, it was during the day, it was VFR and I was doing things like I expect guys to do. I used the radar, used all the aids; the main thing Col Burns and I were talking about this very situation, those rugged Olympics. He's the type of guy who has been up there hiking with Boy Scouts, he's been up there elk hunting, he's been up there fishing, and when we were looking at that rugged terrain, dangerous, involved with proper descent monitoring and so forth, and we were talking on this very subject during my flight evaluation just one month ago, the various techniques. We just never wanted to descend below 10,000 feet.
>
> The reason I am saying this, I am convinced that Col Burns was totally aware, more so than anyone else, about that terrain and about our procedures for not wanting to get down among the mountains in that airplane. ...The terrible irony of it is that Col Burns and Col Thornton were involved with the crash, and they were also involved with this special course [TERPS, to prevent such a thing].

The primary tools the navigator uses to monitor the descent and approach phases of the flight are a terrain chart of the area[105], the radar and the pressure altimeter. Backup devices such as the dead reckoning computers (ASN 24 and ASN 35) would have key points stored such as the base location and the location of major mountain peaks so that if all other equipment failed you would have some quick bearing and

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105 Most experienced navigators would make up their own folder or binder of terrain charts for approaches at all of the bases they routinely flew into, prominently annotating special features to be concerned with, for example Mt. Fuji near Yokota AB. Pertinent information such as their longitude and latitude location would be annotated along with range and bearing to primary radio aids (TACANs, etc.) and concentric circles of equal distance -- 5, 10, 20 nm, etc. -- out from the base TACAN. This would permit easy and quick reference for equipment such as the radar, radio aids and the doppler driven navigational computers (ASN 24 and ASN 35). It is noted, ironically, in one of the testimonies that a new policy had been instituted that disallowed navigators to use their own annotated terrain charts because it was felt that they would become out of date over time and no one would continue to reinvest all that energy into re-annotating new charts. So they had to use brand new charts each flight, which is a pain because they're huge and unwieldly for just the local area you need. This whole policy seems rediculous to me since the key thing the nav uses the chart for is relative location of Mountains and destination airport, which don't move around all that frequently.

range indication to terrain hazards. The TACAN would be set to the base location or appropriate VORTAC for the descent and approach. The job was simply to monitor location, altitude and clearances. If a clearance was inappropriate it would immediately be communicated to the pilot and he could respond by withholding descent while verifying with ATC on the clearance. Pilots worked off of approach plates and airways charts which only have clearance information in their close vicinity. Under radar vectors which took you off established airways the pilot would be left entirely dependent on the navigator for terrain clearance information. An experienced pilot who worked his crew effectively would check whenever he got a new clearance in the vicinity of terrain: "Does that look okay, Nav?"

On this flight, it is likely, as we have seen earlier, that the radar was unusable due to maintenance problems. With a properly working radar, the monitoring job of the navigator is quite easy. Mountains simply stare you in the face on the radar screen and it is very easy to tell where you are relative to them (bearing and distance) and whether you're above or below them. The radar is so helpful in this respect that even if you've lost other navigational aids (VOR, TACAN, included) and are unsure of your exact absolute location, you can keep from running into mountains because you can tell your relative location with respect to them. Without radar, the navigator must be even more diligent, using other aids such as the TACAN or his nav computer to track the aircraft's position. The job is still the same though -- know where you are at all times and where you're headed, vertically as well as horizontally. The less aids you had operating properly, the more important the effort was to assist in tracking the location of the aircraft.

It would be reasonable to assume that the 40641 crew was capable of knowing where they were (with or without radar) and what clearances would be inappropriate. The were handicapped with respect to equipment, with the radar inoperative, the primary nav computer (ASN 24) malfunctioning, and the secondary nav computer (ASN 35) not designed to give range and bearing to a point (only distance to the next point and distance left or right of the course between two latitude/longitude points), they may have been down to the TACAN/VOR which sometimes breaks lock. Nonetheless, this airplane had no recent record of such radio aid problems (Vancouver Center would have been notified of minimum nav aids if they were totally out) and even dead reckoning from a known position from Victoria VORTAC would have enabled the crew to know roughly where they were. Anyway, such a serious situation would have called for extreme vigilance on navigation effort. With a Lt Colonel Wing Training Officer as navigator and a Lt Colonel Wing Standardization and Evaluation Officer as a Flight Examiner traveling on board (although not as an active "on duty" crew member), there should have been ample motivation to carry out their duties to the letter.

What could have possibly happened?

Why was the wrong clearance *not* caught?

We can inquire into this question paradigmatically, the same as we did with the controller. That is, what patterns might this situation be representative of? Even with all of the contextual elements mentioned above that should provide a cognitive framework that would protect crew members, at least five on duty in this case, from letting such an error escape their notice, there are contextual elements that can structure a somewhat different pattern.

Experience:

Let us begin with a closer examination of the crew complement, their qualifications and experience. The Safety Investigation Board described all flight crew members in their aircrew analysis as "qualified and current in accordance with all Air Force and MAC directives to perform his assigned duties as a C-141 [crew position -- aircraft commander, navigator, etc.]." The Collateral Accident Investigation summarized all testimony relevant to the crew with:

> The deceased crew members on this flight were considered to be well qualified and extremely conscientious in their crew duties. ...No evidence was uncovered which reflects that any misconduct on the part of any member of the crew in any way contributed to the accident. ...Flight evaluation records disclosed that the crew of MAC 40641 was qualified in accordance with applicable directives. ...Air Force Forms 1042, "Medical Recommendation for Flying Duty," revealed no medical problems existed for any member of the crew which could have contributed to the cause of the accident.

While all of this is true and factual it does not penetrate deeply enough into the experience structure of this crew. Performance (training and flight) evaluations all carry the context of a "testing situation." A crew member's cognitive framework is different than it is on routine, unmonitored flight situations. For example, there is no question that poor performance on a flight evaluation or in a training situation would certainly raise concern over the individual's capability to perform unmonitored on the line. And excellent performance is an indication that the individual can do the job. However, in the context of the monitored training or evaluation environment, the crew member *expects the unexpected.* He knows he will have simulated emergencies popped on him; he knows the examiner will be trying to "trick him" into accepting a wrong altitude clearance. His studying and practice help him deal with those situations and pass the evaluation successfully. "No-notice" check rides are one way to try to measure actual line performance, which encourages one to stay up with the regulations, procedures, flight bulletins, etc. But, once the flight examiner boards the airplane the crew member(s) being evaluated (and by the way, everyone is on their toes even if they're not the one being evaluated) are in a more alert state to anomalies, actual or artificially imposed.

One Flight Standardization and Evaluation Officer, a Major, stated that the issue isn't proficiency. We have people, he said,

> ...that are capable of making landings, takeoffs, navigators that are capable of monitoring approaches and departures, they shoot three stars. This is my job to go out and see the "can" part of it -- can the person do it and did he do it, in the evaluation. I don't have any qualms in saying that everybody on that crew well filled the "can" part, or they could do the job, and our evaluation records show that on a single incident or at a specific time they did do the job when we evaluated them.
>
> Now we are faced with the problem of *will* they do it, and the fact that you [the accident investigator] and I are sitting here talking is pretty clear that they didn't, and that has to be supervision somewhere. They didn't do what they could do.

There are potentially many factors involved with the question of *will they do it.* Experience is one and it behooves us here to step out of the details of this accident inquiry for a moment to contemplate and understand the relevance and significance of experience.

Experience plays a crucial part in the process through which human beings acquire ability and skills as they become expert in some area. There is no substitute for it; you cannot "book-learn" experience. Adults go through an experiential process of acquiring skills that begins with the novice stage, which involves learning rules for determining actions on the basis of "context-free" features decomposed from the task environment. The process passes through stages of advanced beginner, competence, proficiency and culminates in expertise, where the experience base is situationally deep. [377] That is, through experience we build immense numbers of classes of recognizable situations. These become part of our mental framework from which we view the world.

The *novice* or beginning student lacks any coherent sense of the overall task and judges his performance mainly on how well he follows his learned rules. In piloting, for example, he learns to read the airspeed indicator and altimeter and to control airspeed with the yoke and change altitude with the throttle. These rules ignore context; they do not refer to other air traffic, terrain and so forth. As the novice gains experience actually coping with real situations he starts to be able to recognize example situations he has encountered before. That is, the *advanced beginner* starts to recognize situational aspects on the basis of experience, as well as the objectively defined nonsituational features recognizable by the novice. He becomes capable of scanning for other airplanes and steering clear of terrain while keeping the airplane under control. But his focus is still on rule following and his performance, while improved, remains slow, uncoordinated, and laborious. With increasing experience, the number of features and aspects to be taken account of becomes overwhelming and to cope with this information explosion he must learn how to organize it. To perform competently requires choosing an organizing goal or perspective. This stage involves both uncertainty in the environment and the necessity of a choice by the task performer; thus *competence* begins to incorporate *emotion* into the experience.

> The novice and the advanced beginner applying rules and maxims feel little or no responsibility for the outcome of their acts. If they have made no mistakes, an unfortunate outcome is viewed as the result of inadequately specified elements or rules. The competent performer, on the other hand, after wrestling with the question of a choice of perspective or goal, feels responsible for, and thus emotionally involved in, the result of his choice. An outcome that is clearly successful is deeply satisfying and leaves a vivid memory of the situation encountered as seen from the goal or perspective finally chosen. Disasters, likewise, are not easily forgotten. [378]

Almost colliding with another plane because you forgot to check final before making your last turn, for example, tags that whole situational experience to a strong emotion. In a whole situation, such as this, certain elements stand out as more or less important with respect to the plan that was chosen, while other irrelevant elements are forgotten. The plan was to execute a left hand VFR approach; the important element remembered was that not checking for something you didn't expect, the guy doing a straight-in final, almost cost your life.

> The competent performer, gripped by the situation that his decision has produced, experiences and therefore remembers the situation not only in terms of foreground and background elements but also in terms of senses of opportunity, risk, expectation, threat, etc. These gripping, holistic memories cannot guide the behavior of the competent performer since he fails to make contact with them when he reflects on problematic situations as a detached observer, and holds to a view of himself as a computer following better and better rules. However, if he does let them take over, these memories become the basis of the competent performer's next advance in skill. [379]

As experience increases, there is more and more involvement and less detachment. At the competent level, planning is detached and there is a conscious assessment of elements that are salient with respect to the plan, and analytical rule-guided choice of action, followed by an emotionally involved experience of the outcome. In *proficiency* there is a break through in "seeing" situations in a more engaged sense.

> Considerable experience at the level of competency sets the stage for yet further skill enhancement. Having experienced many situations, chosen plans in each, and having obtained vivid, involved demonstrations of the adequacy or inadequacy of the plan, the performer sees his current situation as similiar to a previous one and so spontaneously sees an appropriate plan. Involved in the world of the skill, the performer "notices," or "is struck by" a certain plan, goal or perspective. No longer is the spell of involvement broken by detached conscious planning.
>
> There will, of course, be breakdowns of this "seeing," when, due perhaps to insufficient experience in a certain type of situation or to more than one possible plan presenting itself, the performer will need to take a detached look at his situation. But between these breakdowns, the proficient performer will experience longer and longer intervals of continuous, intuitive understanding.
>
> Since there are generally far fewer "ways of seeing" than "ways of acting," after understanding without conscious effort what is going on, the proficient performer will still have to think about what to do. During this thinking, elements that present themselves as salient are assessed and combined by rule to produce decisions about how best to manipulate the environment. The spell of involvement in the world of the activity will thus temporarily be broken. [380]

A proficient pilot may sense that he has encountered a wind-shear during a banked turn on final but then he consciously decides whether to stay in the turn, increase power, pull the nose up, roll out and excute a missed approach or some combination of these. The proficient task performer is immersed in the world of his skillful activity, sees what needs to be done (recover from the effects of the wind-shear), but *decides* how to do it.

The *expert* not only has situational understandings spring to mind, but also associated appropriate actions.

> The expert performer, except of course during moments of breakdown, understands, acts, and learns from results without any conscious awareness of the process. What transparently *must* be done *is* done. We usually do not make conscious deliberative decisions when we walk, talk, ride a bicycle, drive, or carry on most social activities. An expert's skill has become so much a part of him that he need be no more aware of it than he is of his own body. [381]

The expert pilot who has experienced similar wind-shear situations reacts instinctively to it. As experienced-based similarity recognition produces the deep situational understanding of the proficient performer, so the expert performer's experience in successful decisions, actions or tactics for the understood situation result in an "instinctive" response.

Experience and skill level vary for different aspects of tasks. To someone who has never flown an airplane, the inside of an airliner cockpit appears to make flying seem impossibly complex. The recently qualified copilot is not intimidated by the cockpit; he understands the systems, controls and procedures. He has the skill to fly the airplane from takeoff through landing. He is perhaps even expert in those skills within a narrowly defined context and may be as smooth as the gray-haired 20,000 hour captain. But the 20,000 hour captain's experience base is much broader in context. He has encountered perhaps tens of thousands of more situations than the young copilot and thus has an awareness level and repertoire of actions or decisions that make him expert in a way that the relatively inexperienced copilot cannot possibly be. Experience translates to safety margin.

We use training to try to compensate for this. Through simulated situations we try to incorporate as much "experience" as possible. We introduce emergencies, wrong clearances and so forth. We try to create in a practical way all the possible situations you may encounter so that you can experience recognizing them and responding to them. Training provides experience with rare events and reinforces these through periodic refresher training. It is essential for anyone who flys. But obviously it is no substitute for actual line flying experience and, as I mentioned above, it constitutes a framework somewhat different than that which obtains outside of the monitored environment. Only the exposure that comes with time at the task can address that kind of experience and those who have developed expertise through a lot of experience know that intuitively, even if they have trouble articulating just what it is that experience does for them.

Experience is context sensitive and our expertise, our ability to sense situations and react to them, is relative to the context from which we gained our experience. If we routinely fly in environments where controllers are known to be "a bit shaky," weak or not up to professional expectations with a propensity for errors, our experience will tell us to be wary and to question in our mind every instruction we get from them. This would be just like we do for the "simulated controllers" in our simulation training environment. On the other hand, our experience with competent, professional controllers such as those in the U.S. builds a large memory base of positive emotional experiences. We build a sense of confidence, a sense of security, a lack of threat from the environment when under "positive radar contact" and control. In the U.S. there simply are not a lot of disastrous outcomes from controller directives. People with a vast amount of experience, such as Col Burns with over 7500 flying hours, however, know things can still go wrong because they have been flying long enough to experience failures of one sort or another, sometime, somewhere in a way that has had an emotional impact on them. This affects the way they go about their routine business of flying. People with very little flying time like copilot 2Lt Arensman with 380 hours and only 180 in the C-141, have a very narrow context of experience and are likely not to be as wary as the old-timers.

The Air Force, due to its mission, the structure of its staffing policy and the cost of its training, upgrade their pilots much sooner than the airlines. For example, I once flew with an aircraft commander who at that time was the youngest AC in the history of MAC. As AC he had responsibility for an eight million dollar airplane[106], the effective and safe accomplishment of an international cargo (and/or passenger) mission flying throughout the Pacific and through the airspace of several foreign countries, flying in all types of nasty weather such as the infamous squall lines characteristic of the South China Sea, and he had the responsibility for the leadership and welfare of a crew of at least six flying professionals. He had to make decisions on aircraft worthiness for flight if there were questionable equipment and maintenance issues. He had to know all the pertinent regulations, procedures, and operational directives. He had to be concerned with hostile fire while taking his airplane and crew into various bases in Vietnam to deliver essential cargo or "med evac" out a plane full of wounded soldiers. He was 23 years old.... Needless to say, although he was a competent young man, the crew watched him like a hawk and were most attentive to every detail of their own duties, as we endured a mild but sustained pucker factor throughout the trip.

We have discussed the qualifications and demonstrated proficiency of the 40641 crew; let's now reexamine the crew's experience level. If flying time is to be used as an indicator of experience, we need to calibrate ourselves. That is, its context must be understood. Any MAC pilot (who can see past his ego) will openly admit that 1500 hours in a jet fighter is a lot more "flying" experience than 1500 hours in a C-141,

106 Cost in 1965.

even though they are both recorded in much the same way as "flying time" on the pilot flight log. One flight from Yokota to McChord results in 91/2 hours of "flying experience," but there is only one mission preparation and flight plan, only one takeoff, departure, and climb, and only one descent, approach and landing. The rest of it is referred to as "droning across the Pacific" with the autopilot coupled to a computer, making a routine radio call every hour or so. The same amount of time in a fighter would likely take 6 to 12 flights and several crew duty days, as the duration of an individual flight is typically 30 to 90 minutes. It takes a lot of flying to build up time in a fighter and thus the same number of hours represent more flying experience. For fighter pilots, 1500 hours is a considerable amount of experience;[107] 1500 hours is relatively low time for C-141 pilot experience.

1Lt Evans, the 40641 aircraft commander, had a total flying time beyond pilot school of 1180 hours. He had just upgraded to AC in December before the March accident. In fact, he was perceived as so new that most of the crew members and squadron people who mentioned him in their testimony (including his squadron commander and an individual who was part of the crew on the earlier part of the ill-fated mission) thought that Capt Eve, the augmenting pilot, was giving him his second "buddy-ride" on this mission. New AC's are required to have qualified AC's as copilots for their first two trips to help them build confidence after their initial upgrade. As it turns out, he had completed his second buddy ride a short while earlier and Capt Eve just happened to be scheduled to go on this mission.

2Lt Arensman, the copilot and sitting in the right seat at the time of the accident, was essentially green with only 180 hours beyond pilot school. Deducting time for aircraft type training and rating upgrade, that might account for only three or four trips out in the Pacific "MAC system."

The augmenting pilot, Capt Eve, it was noted earlier, was being considered for instructor pilot upgrading to begin that summer. He had 1345 hours beyond pilot school and had his initial upgrade to aircraft commander less than one year before the March, 1975, accident in May, 1974. Recall that he was in the jump-seat.

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107 For example, a good friend of mine who went through nav school with me, recently retired from the Air Force after 21 years with a total of 2200 hours, which he told me was very typical for people flying the type of aircraft he was in. His entire flying career was a back-seater in an RF-4, reconnaissance version of the F-4 fighter-bomber. As a C-141 navigator, I had 2500 hours built up after a short 4 years, which included a year for OTS and nav school. That meant roughly 700-800 hours flying time per year versus Bill's roughly 100 hour per year average.

Lt Col Thornton, the navigator and Wing Training Officer, was seemingly well experienced with a total of 3330 hours, with 393 in the C-141. But testimony indicates that his navigational experience was in fact quite limited; less even than 1Lt Lee, the augmenting navigator who had a total of 965 hours with 780 in the C-141. A Wing Standardization Navigator testified that:

> Col Thornton, even though a Colonel, a navigator, has never really navigated, that is in a nav seat in an airplane, not only a 141, throughout his career, because he has been an Electronics Warfare Officer, so he was assigned to this Wing as an Electronics Warfare Officer. But because he was also a navigator, had gone through navigator training first,[108] then Electronic Warfare Officer School, he had navigator wings, he came as Electronic Warfare Officer and as navigator, and he was to be trained, qualified, and maintain his currency as a C-141 navigator. But this happened within the last two-year history. So what I am saying, so far as I know, Col Thornton didn't have real extensive navigation background.

In response to the investigator's followup question, "But he was qualified as a [primary crew] navigator?", the testimony indicated that, yes he was as of November, 1974, but because of his Wing Staff duties, his five-month eligibility period for his evaluation was slipping by rapidly (end of November 1974). In November the squadron didn't have a Flight Examiner nav available to take Col Thornton out in the system for his annual so his eval was administered by a Reserve Flight Examiner which required a special permission waiver from Wing Standardization. Testimony indicates that this man, a Major, was a very competent Flight Examiner. The point explored by the investigator was if there was any doubt that he, Col Thornton, was a fully qualified navigator. The response was, "No doubt at all."

Lt Col Burns was the most experienced crew member on the plane with 7550 hours total, 1505 in the C-141. But he was not on duty and it is thought, by those who knew him well, that he must have been off headset or not in the cockpit.[109] Col Burns joined the crew at Clark AB after he had just completed an "in-country" flight evaluation (Clark -- Vietnam -- Clark) with another crew. He hopped the 40641 plane and instead of getting off 40641 and crew resting at Yokota, he chose to "dead head" home with the crew because he was to go on leave that weekend. He was well over

108 My note: Col Thornton completed nav school in 1960.

109 The flight deck of a C-141 can get cramped. There were five people sitting at duty stations; there is room for a couple more to sit on the lower pilot's bunk at the back of the flight deck. Often times an additional crew member may stand behind the jump-seat, between the navigator on the left side and the engineer on the right side during a descent. But these are normally only people who are part of the active crew; anyway, closer to the approach everyone would need to be sitting down and buckled in. There had to be crew members down on the cargo deck with the passengers. It is unknown who was sitting or standing where, other than the crew members who were strapped into their seats.

even a 24 hour crew duty day. In responding to a question, "Even if he wasn't on duty would he have taken part in what was happening in the airplane?", the person testifying stated:

> The first comment off the cuff I made about his participation in this flight, I said he had to be off headset, back there riding, trying to get home. Col Burns was due to go on leave that weekend, so I feel he was probably pushing himself to get home, he was riding in the back of the airplane[110] or somewhere back in the airplane, speaking as a euphemism, that is not even on headsets. He might have been, but he probably wasn't monitoring instructions, maybe just interphone chatter or something.
>
> I personally feel he had nothing to do with that flight. If he was involved with that flight it just never would have happened. I feel so strongly about that, because I know him inside and out as far as standardization goes, especially since we had just flown that together, that very area, talking about this very thing.

And a bit later in the testimony, responding to follow-up probes about which navigator(s) might have been involved in monitoring what was going on, he stated he couldn't say about Lt Lee, but that:

> My only personal feeling is that Col Burns had nothing to do with being in the seat, I am convinced, or evaluating. I know he wasn't evaluating because it's already established that he was well beyond his augmented crew duty time. Another ironical part of that Change 6 to 55-1 I showed you has the statement now, which was not in effect at the time of the accident, that says Flight Examiners will not exceed, deadhead crew members will not exceed an augmented crew duty day which is 24 hours. So now there are specific instructions which came out the next day after the accident. That would have disallowed Col Burns to fly in that airplane.
>
> I am sure that Col Burns would not administer an evaluation when he goes beyond his 24-hour crew duty time consideration because he and I have been in February in the same airplane going over to Yokota, we had a crew duty time consideration which one of the navigators whose work was 16 hours, he cut him off right at 16 hours, that was it, he would not administer an evaluation beyond that 16 hours.

Experience as a general issue was brought up voluntarily in testimony and was also uncovered by investigative reporters as an issue of major concern among the flying crews at McChord. In response to the open question asked of all of those who testified, "Is there anything you can add that might help us in this investigations?", the Officer in Charge of the Wing Flight Simulator Section responded with the following:

> One of the things I have been concerned with personally is the fact that our experience level is decreasing. In January of this year everyone who was within two years of retirement or separation, for whatever reason, was removed from flying status. I felt this was quite an incursion into the experience level of our assigned pilots. With the fact most people have a five-year commitment, that in many cases only leaves them three years after graduation from pilot training, and they aren't really accumulating a great deal of experience in that period. In my opinion there is no real solid base of experience available today and I think

110 In the first instance he means the back of the flight deck.

> this is a major safety consideration. I wouldn't say it's a causal factor in this accident, I wouldn't presume that, of course, but it is of major concern to myself and just about everyone I talk to, the fact that our experience level is so low today.

It is insightful to follow the line of questioning and response that followed the above statement. Col Pennella, the Investigating Officer asking the questions, also a pilot formerly on C-141's, does not seem to pick up on what the Major is saying; in fact, he seems to steer the conclusions away from the perception of a general pattern the Major is trying to describe.

> Q: Do you go out and fly with some of the crew members, not necessarily this crew, but other crew members on trips?
>
> A: I did before January, at which time I was in this group of people who were furloughed or grounded.
>
> Q: During that time, did you find there was a deficiency in the flying proficiency of the younger people?
>
> A: Actually proficiency is not as big a factor as just the overall experience. The people make the decisions based on the information they have and the experience they have accumulated over the years, albiet very few years, but I am one of the types who feels experience is garnered over a longer period of time and judgments made under given conditions may vary as one's experience increases.
>
> Q: What you are saying, then, as I understand it, is that it's not so much their inexperience and their ability to actually handle the airplane, but more or less their ability to handle an air crew, is that what you're saying?
>
> A: The first part of your statement is accurate, that their hands-on proficiency, basic motor skills, are good, excellent in fact in most cases, and their ability to handle a crew is really not a serious problem, as I see it. The thing that bothers me is their exposure to worldwide operations and very few situations are really stereotyped to the point where you can just regurgitate and answer on command, but rather over a period of several years a person would naturally, I think, produce a more logical decision under the same conditions with less strain, I suppose you would say, or less thought, based on his experience. This is one of the things that you just are going to necessarily find is less than perfect in the younger man who doesn't have this experience.
>
> Q: I am not sure I understand what you are saying.
>
> A: What I am saying is that in my opinion there is no real substitute for chronological exposure to this worldwide type operation where you're going to be out in the system flying different types of approaches all over the world, and also there's a certain amount of knowledge transfer takes place from the older pilots to the younger ones in their flying that helps present a broader experience base and a broader knowledge base.
>
> Q: What you are saying, then, is although they are proficient flying the aircraft, handling their crew, with a little more experience they could do this better?
>
> A: I think that's probably true, yes sir.
>
> Q: On this crew there was some experience. We had two navigators on board, Lt Colonels. Of course one of them probably not working, Col Burns, but Col Thornton was probably working. In light of what you say about experience, do you think this could have affected

this portion of the leg, even though the pilots themselves might have been a little inexperienced, there was somebody on board the aircraft during the approach that was experienced?[111]

A: Yes sir, that's true, the navigators, Col Thornton and Col Burns, I knew them both personally, and I feel they were quite highly qualified.

Q: You knew them personally. Could you elaborate on what type of individuals you thought they were?

A: Col Thornton was the Chief of Training, who was my direct superior, and I felt that he was an extremely conscientious, thorough, very competent individual in this staff work that he was associated with. I never flew with him, but I am sure this type of feeling would carry over to whatever he did. I was greatly impressed with him.

Q: Do you feel confident if he was working as a navigator for this approach that he would have been in his seat and with appropriate terrain maps out and following the whole approach closely?

A: I'm sure he would have, yes sir. Col Burns also, although I have never flown with him, I have known him personally. His reputation is such that he's well known as a stickler for detail, for accuracy, professionalism.

There were no further questions and the witness withdrew from the hearing room.

Comments from several McChord C-141 crew members were made during a base-wide aircrew meeting, which had several hundred crew members packed into the 500-seat base theater. The meeting was called right after the accident on Friday, March 21, by Maj Gen John Gonge, commander of the 22nd Air Force (headquartered at Travis AFB, CA) of which McChord's 62nd Military Airlift Wing is a part. Gonge had come to the Northwest to look into the crash himself. He decided he wanted to talk to all the air crews in the base theater while he was there. The meeting was closed to the public but investigative reporters for the Seattle Times, Seattle Post Intelligencer, and the Tacoma News Tribune inverviewed many of the air crew members who were there. Some of the more experienced officers were bold enough to bring up policy issues related to experience, among other factors. Experts from key Seattle Times reports illustrate the concern over inexperienced crews. It begins with the comments of a veteran C-141 aircraft commander who acknowledged that, in his opinion, the FAA was not entirely to blame for the crash.

111 My note: Observe also that this testimony was given the day after the testimony quoted earlier, which pointed out Col Thornton's very limited navigational experience. The person giving the testimony, of course, is not privy to what others have testified; but, Col Pennella, the Investigator doing all the interviewing, obviously is.

..."It was a (MAC) institutional error, too," the officer said. The Military Airlift Command "had slaughtered 25 per cent" of its most experienced pilots for budgetary reasons, he said. Other budgetary reductions have caused the cutting of corners on flights so that crews "are being pushed as far as they legally can."

As a result, inexperience coupled with crew fatigue must account in part for the fatal crash, the pilot said. The pilots of the C-141 were "qualified but inexperienced," he said. "It was a case of a pilot with 1400 flight hours watching one with 1100 hours," he said. He described 1500 to 1600 hours as the desirable minimum level, the "dividing line in order to be tuned in to all the nuances and problems you might run into."

A spokesman for McChord declined to reveal the official flight-hour records of 1st Lt Earl R. Evans, the pilot, and Capt Frank E. Eve, the co-pilot, of the doomed plane. "That is under investigation," the spokesman said.

But the aviators said pilots now flying the Starlifters have a low level of experience under a policy instituted in January. At that time Gen Paul K. Carlton, MAC commander, ordered experienced pilots furloughed from flying to save money. A pilot is furloughed if he has 24 months or less left of his active-duty time. That means he is given ground duty.

The policy to furlough pilots is a money-saver because fewer flights are operated. The costs of training flights to maintain proficiency ratings are reduced and there are fewer maintenance flights. Flight pay is still earned by many in various job categories but the overall number of flight positions is cut. In the 62nd Wing, there are 44 pilots furloughed, representing 18 per cent of the pilot strength, the McChord spokesman said.

"We said it at the time that this can only lead to an accident," the pilot said.

One furloughed pilot estimated the loss at "35 to 40 per cent of the experience level." The McChord spokesman said there was no such estimate available. The furloughed pilot said Carlton was "under the gun" of the Air Force to cut expenses. "But he cut in the wrong areas," he said. "He cut out the experienced pilots instead of cutting the weak pilots and those who don't care for flying. Not all pilots love to fly.

"Those who love to fly and have the experience are being grounded. They're so disgusted that many are putting in for early-outs and leaving the Air Force." [382]

Another article had similar comments from McChord crew members. One person commenting on the mistaken descent into the Olympics.

The plane probably began to descend to 5,000 feet, as instructed in a mistake by a Federal Aviation Administration controller, about 65 miles from McChord. The Olympic Mountains are more than 40 miles from McChord. The plane may have reached its ordered 5,000-foot level when it was about 45 miles away. The impact site was 43 miles from the base. It takes 20 to 22 miles to descend from 10,000 to 5,000 feet in a C-141.

"An experienced navigator knows that. A pilot familiar with the area also knows it, and if he had sufficient experience he would simply refuse a clearance to go to 5,000 feet in that area," one of the pilots said.

"But if you lack experience, you're afraid to challenge the air controller. In pilot training you learn to rely on the controllers. It's only with the accumulation of experience that you learn to question them, if necessary."

"Controllers are human, too. They make mistakes, some times small ones, but important. They may say 'left' when they mean 'right.' But I am not saying they're all fouled up. Yet, there are many times I have had to question a clearance or remind them that they'd forgot to 'hand you off.' You have to call them up and ask them, 'you still with us?' The pilot and controller must work together.

The danger is when a crew is so tired that it relies totally on the controller." [383]

And a follow-up article reported that the Air Force-wide policy had hit McChord particularly hard.

The Air Force has grounded "less than 200 pilots" under a new budget-cutting action imposed in January, a Pentagon public-information officer said yesterday. Capt John Worthington offered the comment after The Times Friday described the policy of "furloughing" or grounding pilots with less than two years left on active duty or with more than 1500 flight hours accumulated.

The furlough policy has hit the 62nd Military Airlift Wing at McChord Air Force Base particularly hard. Earlier last week a McChord public-information officer said 44 pilots in the Wing have been grounded, representing 18 per cent of its C-141 Starlifter commanders.

Numerous officers have criticized the furlough policy in talks with a Times reporter, saying that it has reduced seriously the level of experienced pilots available to fly the big cargo jets. The pilot and co-pilot of the ill-fated C-141 which crashed in the Olympics March 20 were reported to have 1100 and 1400 hours and a source described them as "qualified, but inexperienced."

Worthington could offer no explanation why a single unit like the 62nd Wing at McChord has furloughed roughly one-fourth of the Air Force-wide number of grounded pilots.

The grounding was intended to reduce flight operations overall and save money. A local commander may request permission from higher authority to institute such a budget-cutting program.

The furlough policy was one of several Air Force actions discussed by officers and enlisted men in articles in The Time Friday. Later that day, active-duty personnel received orders not to talk to reporters and "they're really trying to find out who are those who have been talking," one source said.

The Military Airlift Command headquarters at Scott Air Force Base, IL, issued a statement shortly after The Times articles that the Air Force would make no comments on the fatal accident until an investigation is completed. [384]

A Reserve pilot compared the experience of active duty with Reserves. "The people who are flying currently in the active duty establishment, practically all of them are minimal in experience. In contrast, the experience of Reserve pilots is quite high, with total flying time often in excess of 5000 hours." [385] Another officer commented: "With the pilot cutbacks, MAC flight crews are being pushed to their physical limits." [386]

Other than reporting total flying time, no comments were made regarding experience in either Air Force investigation analyses, discussions or summaries.

The Routine:

Continuing our cognitive framework inquiry on the question of why the wrong clearance was not caught, we turn now to the routine nature of this leg of the flight. Although most west bound flight routes take McChord airplanes through Hickam AFB, Hawaii, Wake Island or Guam, and then to Clark AB as a shuttle point for Southeast Asia missions; virtually all McChord flights return through Yokota AB, Japan, and then over NORPAC, the Northern Pacific overseas airway system. For one reason, this is the "great circle" route, or shortest global route from Clark to McChord. Once the Sandspit VORTAC on Queen Charlotte Island is reached off the coast of British Columbia, it is all routine continental airways to Victoria (410 nautical miles) and radar vectors to McChord (an additional 105 nm). There is a sense that the last long leg of a long trip is just about over and there is always a warm feeling about getting home soon. The relative lack of voice traffic on the single-side-band high frequency communications over water is replaced by increasing radio chatter on the VHF and UHF radios used to communicate with Air Traffic Control in Canada and the U.S. The route is familiar, the routine is familiar. And when the controller reports "radar contact" after having you "squawk" a 4-digit code on your transponder and "ident," causing it to momentarily light up brighter on his radar screen, there is a subtle feeling of relaxation as you know that the progress of your airplane is being closely monitored by ATC.

And then, as you get closer, you receive the familiar radar vectors and altitude clearances as you are now under positive radar control. You're tired and hungry and thirsty. And just maybe you slack off just a little bit on your attentiveness as you are lulled into a sense of security by the familiarity of it all, and the perception of low risk because, after all, these are the controllers in our own back yard. They handle the multitude of commercial airline traffic that runs so safely every day of the week. They bring in McChord airplanes over this exact route many times a week. The crew is preparing for the last portion of the flight; the pilot gives his descent briefing, confidently commenting on the Olympic Mountains as the major terrain hazard. We know -- everyone knows -- you maintain 10,000 feet until clear of the mountains before stepping down to lower altitudes. Why wouldn't you be doing that? There is no reason; we *always* do that when approaching from the north. Controllers obviously know that.

Sure, you monitor your radar for terrain while you wrap up you flight logs. The pilots are calling ACP to update the block time, request customs, a crew bus and transportation for the passengers. Cockpit chit-chat has picked up a bit after the descent briefing -- you're not in the approach pattern yet. Someone's going fishing or skiing this weekend, someone's working on his house, someone's going on leave. All is well, were under radar contact on the same ol' vectors to McChord. We've done this a million times before.

But your radar's not functioning properly; still can't get the tilt to work. Oh well, we knew that when we decided to take it as is from Yokota. Good thing there's no severe thunder storms in the area. Perhaps you shut it off since the tilt problem prevents any usable returns. The dead reckoning nav computer, the ASN 24, you might have had set on McChord as a backup so you could read the distance to it; but it is behaving erratic and the information is unreliable so you probably had that shut down too. After all, its just a backup and not all that terrific; it can quickly be off a few miles, which is no big deal over the Pacific, but rather inaccurate for close in stuff. The old ASN 35 nav computer is a pain in the ass under the best of circumstances, and for bearing and range stuff, it doesn't have that kind of readout. If its not shut off, the information requires some plotting to interpret properly. Besides, we've got multiple TACAN and VOR nav radios and we're under routine radar vectors. We all know the routine. We *experience* the same thing over and over again. We always have good positive emotions attached to our experience as we come into McChord. We're just about there anyway. The pilots have it under control; there's even an extra AC in the jump-seat monitoring everything. The VOR's and TACAN's are tuned in and their CDI's set in case ATC looses radar contact. And we never *experience* problems here; Seattle Center's got us and were almost home. In the 1100 or 1400 hours the two young pilots have, perhaps they've never experienced any problems with ATC in the U.S. and certainly not coming into McChord.

The navigator's likely got the terrain chart out and sure enough, the Olympic Mountains are right where they always are and we're flying over them on radar vectors, just like we always do. And the navigator keeps an occasional eye on the TACAN at his station (he only has one repeater instrument with bearing and distance readout, the pilots must set it to what they need). And boy are we glad to have this long trip over. And now we're just about there because there's the familiar step down clearance to 5000 that we get after we're past the Olympics. We're ready to be vectored straight in for the approach to runway one six. Only 15 minutes to go. The pilot is thinking well ahead of the airplane, he's set for his approach briefing, perhaps he's giving it now since it's straight in on vectors to runway one six and we're already cleared to five. Good time to get the approach briefing out of the way; everyone, especially the pilots and nav, need to focus their attention on the approach briefing -- for safety's sake. Of course it can distract you for a few moments from monitoring the descent.

He's a competent and conscientious young pilot. He's flown this route many times, it's almost second nature. And then --- they went to their deaths less than two minutes later never knowing that the descent clearance, which sounded so ordinary, so expected was but a few moments too early.

And they never suspected for an instant that in less than two minutes the dark clouds of the night and snow they were alertly and comfortably flying through on instruments at the end of a very long and tiring trip would, without warning, turn into a ragged granite wall. They never knew that most of them would be instantly torn in half as the seat belts momentarily did their job. They never new that autopsy reports could explain the horror of their deaths with such clinically sterile statements as:

> **Cause of death: multiple massive injuries; most significant being complete absence of the brain through massive open crush fractures of the skull, transection of aorta and penetrating lacerations of both atria and right ventricle. Rupture of the right hemidiaphragm with displacement of the liver into the right thoracic cavity; extrusion of small bowel; obliteration of pituitary by massive open fractures; all ribs fractured in multiple places with displacement; all long bones fractured except the left radius and ulna; open crush fracture of head and face; fracture with displacement of lumbar spine.**

They never knew any of this as their soft body tissue was shred to pieces becoming one with metal, glass and granite rock over a period of about one one hundredth of a second. The cockpit itself would be so integrated with the jagged mountain face it hit traveling at about 450 feet per second that it would take dynamite four months later to separate it from the mountain.

Such was the result of a false sense of confidence emanating from a tired crew who had *experienced* such positive emotional feelings over the last few minutes of that long 9 hour Yokota leg so many times before. They were almost home.

Ah, but should we not blame the crew for their own demise because indeed they did not challenge erroneous instructions from a U.S. civilian air controller? Did the crew not commit suicide, as the angry two-star General who commanded the 22nd Air Force was reported to have said in a "heated tirade" at the now legendary base-wide crew meeting the day after the crash? [387] The embarrassed General later issued a public denial and then refused to be interviewed further [388], but the description was backed up by numerous sources, from enlisted men to officers. The meeting was described as an "unbelievable scene," a "tirade" of "rather unusual nature." Another officer reported, "the General told us it was inexcusable to fly into that peak, that the crew committed suicide because it had screwed up. ... And [he said] that to an audience that had just lost 10 of its friends."

The General was undoubtedly sad and angry over the loss of one of his airplanes and crew for something that could have been prevented if the crew had been doing what they were trained to do. Is it just a young, relatively inexperienced crew that would succumb to such an error? Consider the reflections, in their own words, of some of those commanders, flight examiners and instructors who testified before the accident board investigator. The crew's squadron commander, a Lt Colonel, responded to Col Pennella's question regarding the normalcy of the procedure for coming into McChord from Yokota: "I have come in from Yokota many, many times, I don't know how many, but had I been the aircraft commander on that airplane I most probably would have done just what they did." A squadron operations officer, a Major, described the normalcy of the route in response to Col Pennella's inquiry.

> The altitudes we normally get are to descend down to the 20,000 foot range as our first descent coming in toward Victoria usually, we are stepped down to 10,000 feet until past the Olympics, and then down to 5,000 feet prior to hand off to RAPCON or a McChord approach control.
>
> Q: Do you ever follow that airway down?
>
> A: It is usually radar vectors.
>
> Q: So unless you have a terrain map you really have no means to determine the minimum route as you're coming into this field?
>
> A: Right.
>
> Q: You rely heavily, then, on the approach controller?
>
> A: Completely, yes. ...We can all look back and say, "Gee, that might have happened to any one of us."

Later, he was recalled to affirm or deny testimony by FAA senior managers that seldom does Seattle Center turn over aircraft to RAPCON at McChord below 10,000 feet. The Major replied that he could *not* affirm that testimony and that he would be working from a framework in which he would expect those clearances.

> I can't tell you specific instances, but it is just my recollection that Seattle on many occasions has cleared me below 10,000 feet, and specifically to 8,000, and I am sure below 8,000 to 5,000, before being turned over to McChord RAPCON.[112]
>
> Q: Would you say that is a common practice?
>
> A: I personally would be programmed for that.

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112 My note: Recall that the letter of agreement between Seattle Center and McChord RAPCON allows for descent below 10,000 with prior coordination. The pilot would have no way of being aware that this background coordination between controllers was going on.

Q: Seattle Center can give you lower with concurrence of the RAPCON, but you would never as a pilot know that this has transpired. What we are again trying to establish is, is this practice so common that it could become part of your routine in your approach here?

A: Yes.

Yet the pilots don't have any chart available for explicit terrain awareness. But it's routine, I guess no one had ever thought they'd need such charts. Instrument pilots always fly using airways charts and approach plates[113] -- they don't have the time or room to be pulling out big terrain charts, do they. And besides, they're under radar control when they're "off airways."

Olympics not on military flight map

A military flight chart used by aircraft skirting the Olympic Mountains shows the Olympics as "one big void."

"It's incredible," a military aviator said. "Unless you know from personal experience that the mountains are there, or can see them during a period of good visibility, you wouldn't know they're there."

The chart, for flying below 18,000 feet, is one used by aircraft flying from Yokota at Tokyo to McChord Air Force Base, such as the C-141 Starlifter which crashed in the Olympics last week, killing 16 persons.

The chart shows the prescribed air route, coming in over Victoria, B.C., to McChord, taking the aircraft just east of the Olympics and over Hood Canal. Minimum altitude listed is 4,100 feet.

The mountains are not shown on that particular chart, yet aircraft easily could veer off to the right as they head for McChord, the aviator said.

"No altitudes for the mountains are listed even though you get into 7,000-foot peaks and higher just a few miles away," he added. "That has got to be changed because that's the one that pilots refer to."

Only a terrain map would tell the plane's navigator that there are mountains to the west. The navigator is supposed to check terrain maps along with the flight charts.

The Starlifter was the third C-141 in two years lost by crashes in high terrain by the Military Airlift Command. [389]

But that's the navigator's job, isn't it? The squadron commander was asked this question.

Q: As far as you know did most of the navigators on the crews flying carry terrain maps with them for the local area here, or for most every place they make approaches into?

A: As far as I know they do.

Q: Navigators make up their own type of book for this type of thing and have them all marked out. Do you know if anybody in this crew might have had something similar?

A: Not having flown with any of the three navigators involved, I couldn't say.

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113 Airways charts show minimum altitude within 100 miles which does you little good when Mt Ranier goes to 14,250, making the minimum en route altitude 16,500. You're already below that at 10,000 feet. And approach plates only have terrain within 25 miles of the runway. The crash occurred 46 miles from the runway.

But a squadron Standardization Navigator describes the recent policy change, correcting the Investigating Officer's perception:

Q: Navigators very often make small charts for themselves using terrain around areas where they make approaches, and definitely around McChord because this is their home station. Do you know if this crew had anything like that, if the navigators on board had their own maps made up for the approaches into McChord?

A: No sir, I don't know, and I would speculate when I say this, but they probably would not. What has happened in the past few months is 22nd Air Force has come out with this CHUM update summary. It sort of discourages, in my own mind, people from keeping their own logs or charts.

Q: That makes sense because they would have to keep them up to date, I guess.

A: Right.

Q: I have in front of me an ONC chart I would like you to look at and see if this is the type of chart the navigators had on this approach, or charts similar to this?

A: Yes sir, I would say that is probably the chart that they had. I know that chart is carried on the airplane.

But even though they're not supposed to use their own "prepared" local area terrain chart, they do have a new chart that they can fold up to the area of concern, so what is the routine, then. Another Standardization Navigator describes it to the Investigating Officer.

Q: What precautions do most navigators take in crossing the Olympic Mountains?

A: There is only one precaution that will suffice if I am giving an evaluation, and that is to know where the airplane is, for starts, and secondly, to know where it's going. Because everybody said, "Well, the pilot should have known where he was and the navigator should know where he was" but that wasn't the important part. The important part was to know where he was going, because the decision to descend, I feel, was made before that was carefully checked out. I made the comment unofficially to you yesterday that if you listen to that tape, the reading goes off the tape something like from the crew back to the controller, "We're level at ten" and the controller says, "Roger, clear from ten thousand down to five." The amount of time, the tone of the voice says, "Okay, out of ten for five" and there wasn't any pause, no mental pause of any turning around, saying, "Does that look good, navigator?" or "Where are we?" or "Is the terrain too high?" Now if the person was fatigued or euphoric over radar environment, I don't know, but I could almost feel the nose of that airplane nosing over on that tape, and that's what happened right there.

Q: What you are saying basically is that the crew expected this clearance and when they received it they followed it?

A: Yes sir.

Let's face it, it's just all so routine. Should we blame the navigator for this tragedy? Do the pilots even *need* a navigator for protection from the Olympics? Airlines don't carry navs and nowadays even C-141s don't carry navs. The crews *know* what to expect. A flight examiner pilot testified in response to the question whether the crew probably got the clearance they expected to receive.

> I've thought about that a lot. ...You generally cross and head toward Bremerton. One thing I thought could have been a factor, was once you pass the mountains, you are on radar vectors at this time, once you pass the mountains it is ordinary, it is common, to get a descent to 5,000 or 6,000 feet to begin your let-down for landing, especially on runway three four. I understand they were landing on one six so they might even have expected it sooner.
>
> So they were expecting a descent somewhere past the mountains at 5,000 feet. They all knew that the mountains were 10,000 feet out there, there's no doubt that they knew it, but the problem was, in the past, I think, their habit patterns are set up so when they got a descent, they knew they were going to get a descent to 5,000 feet, it just didn't ring a bell with them that they weren't where they thought they were. Not only that, but they were just expecting it and it didn't trigger them to think something was wrong.
>
> ...I think we fall into habit patterns, especially flying the same route over and over, you know the radio frequencies, you know the approaches almost by heart, you know what you're going to expect. When you get to Victoria you just start waiting for the transfer to Seattle Center because you know you're going to get it. They give it to you and you know you're going to turn to that heading. To people who have flown this route over and over, it is so repetitious that possibly we fall into a state -- I don't want to say complacency -- but really, it could be that. If possibly someone who had never been to McChord had gotten that clearance to 5,000 feet they might have questioned it more so than this crew did, or I don't know that they didn't question it, or I don't know that maybe their navigation aids were wrong and they fixed themselves somewhere other than where they really were. I don't know that, but I do think that someone else who hadn't flown the route would wonder why they were getting that clearance to 5,000 feet, where these people maybe didn't because they had gotten it before and it just never really dawned on them that they weren't in the position to descent at that time.

And in response to a question concerning how this crew might have been programmed to have accepted that altitude below ten, an aircraft commander, a Captain, stated it wasn't because it came from Seattle Center, per se, that is due to the "trust factor;" but, that it was the expected clearance.

> In fact when the accident happened and we heard what had happened, that he had been cleared to 5,000, it was kind of scary because probably -- I would like to think I wouldn't have taken it -- but I probably would have done the same thing.

The squadron Standardization Navigator stated that the crew would have expected this clearance and when they received it they followed it.

> The mistake that was made is insidious in that the altitude that they would have been descending to, 5000, matched with the altitude that they would have anticipated and should have anticipated, but it was six or seven minutes early, that's all. Had the Navy airplane been given clearance to, say, 5500 or 3500 or anything other than 5000, I feel the mistake would have been caught, but it sounded good, it was just the timing that they didn't check.

A Wing Flight Examiner Navigator, a Major, who worked for Col Burns testified about all the normal things the navigator should be doing during descent, with and without an operable radar and other equipment; but admitted to difficulties sticking to it under the context of radar vectors, of relaxing the monitoring duties a little bit too much. The line of questioning presses the Major hard and probes this issue deeply. Answering another question, the Major turns his comments to the context of being under radar control.

Unfortunately I think what we're getting at is, when we are on radar vectors a lot of us are so dependent on the instructions that we hear on the headset to be absolutely right. In my many years of experience I have to say I have the feeling a lot of times myself, boy, when I hear those instructions in the headset they're valid, do it.

Q: Is it routine to you, then, when you hear an instruction from Seattle Center, to descend from 10,000 to 5,000 feet, to check your positions? Is it also routine for the pilot to wait for your clearance before he starts to descend?

A: No, that's not routine. I think this gets back to the training the pilots receive, the navigators receive right from the first time they get in an airplane in the Air Force -- whatever that little guy in the headset says, you start paying attention to it. This is contrary to commonsense, as it turns out, in certain situations. I think under radar vectors there aren't too may crew members who will say, "Well, let me doublecheck that" and I just don't think it's part of our flight routine.

Q: Do they do it when you ride to check them?

A: If they don't they become unqualified.

Q: Is it emphasized that even though you are under positive radar control you do this, that you check you position at all times regardless of whether you're under radar control or not?

A: Yes, I expect that, sure. ...There are really no exceptions...

Q: ...[and if] the radar set was not working?

A: ...The normal thing is to get radar vectors over in this area, and when you get on a radar vector a lot of times you just depend on their instructions, but you also have everything else working for you [TACAN, ASN 24, etc.] and there's no problem...

Q: What I am leading up to is that the sum and essence of your testimony is that the navigator was deficient, is that what you want to say?

A: No, I don't want to pin it on the navigator in that sense, in those words, deficient, because what we're talking about here is equipment problems also. Now let us say Col Burns or myself were in the seat with no radar, no ASN 24, no TACANs, we'd really be hurting. So now you've got to talk in terms of --

Q: [cutting in] If you didn't have that wouldn't you tell the pilot you didn't have, and also wouldn't you tell him to be extremely cautious on any let-downs or anything like that?

A: Yes, hold on, let's make sure we know where we are. Now unfortunately there are other factors involved here. One of the prime is that under radar vectors you are lulled into a sense of well being that someone else is helping. This is built into us.

Q: You are not saying in order for the navigator to have caught this wrong clearance he would have had to be a highly experienced competent navigator, are you saying that, or could it have been slipped by most navigators that are flying the line?

A: I don't know. I think what I'm saying is I would expect a navigator to catch that.

Q: Is that one of the exercises you use as a routine of your checkride, for example would you somehow run a scenario before a navigator to see if he would check regardless of whether he was on radar vector or not?

A: The scenario would be during an actual inflight evaluation and checking off the rated item for approach and departure monitoring. It's in two places, one on radar, one under the general subject. A typical question would be, what altitude do we clear to, what kind of an approach are we setting up, and so forth? Now, unfortunately, in an area such as that, where there are preoccupations with some other things that could be happening, they could be going through an approach briefing, they could be doing other things. The navigator is required to listen in on that. This goes back to the false sense of security that the crew might have when they are on radar control, they are going on a certain heading, O.K.

Right now we are under radar vector, this is a very common thing for a navigator on his log to indicate, under radar vector control, and then he goes through and he cleans up, so to speak, his paperwork. The procedure now, the instruction now, is to not do anything else, in other words, be preoccupied with the descent, even under radar vectors and so forth. I think this is slightly contrary to the way we've been doing it. Many times I have flown under radar vectors and I've said, "What a relief" because as a navigator I am normally working my tail off, with the normal en route navigation duties. If I get to a point where all of a sudden I am under radar vectors, I heave a sigh of relief, and I can clean up paperwork.

Q: Now that is what you said originally and I want to get it straight. When I asked you before, when you know you are under positive radar control, would it be normal, would it be routine for a navigator sitting in that seat, to check his position when he heard a descent order from a Center, if he heard a descent from 35,000 to 25,000, or from 10,000 to 5,000, would he automatically start to check his position, or should he do so?

A: If he gets a descent from 35,000 to 25,000 I would say no, if there are 25,000 foot mountains in the area we ought to be cognizant of that. However, when we're getting down into the lower altitudes I would expect that the navigator to check.

Q: Even though he was under radar vector?

A: Yes, sure. Because even though you have this false sense of security, you want to always be aware of your position.

Q: Is that the desired result, or is that what you expect the majority of the navigators who fly the line to do?

A: The desired result in accordance with directives or something?

Q: Yes, and in accordance with what you would require when you check a navigator, or is it something the majority of these guys do every day?

A: I require guys to do it and I would expect that they do it. I am talking about unqualifying a guy if, let us say, he gets descent clearance from 10,000 to 5,000 and he is completely unaware of the instruction to do something that could be dangerous, he's going to bust and I am going to talk to the whole crew about it. This doesn't happen too often. Unfortunately when it does happen something like this might happen, I don't know. I don't know the frequency that something like that might happen.

All I can say is, during the evaluations I have administered, the navigator probably is more aware of this very situation, he is more on his toes, so to speak, because he knows I am going to be asking questions about it, he knows this is a special emphasis item.

In the end, we have determined that qualified crew members *can* do the monitoring correctly, but we are left with a vivid view of the different context that surrounds check rides. Unanswered is who *will* do it and *when* will he do it. There was considerable agreement in the testimony over this issue. Another Flight Examiner Navigator observed that even though it is an item of special emphasis in evaluations, he volunteered to the "anything else you can add" question, that:

> I think it's a sense of -- I don't want to say complacency -- but I think whenever you finally make contact, radar contact, and you come under the control of a good radar controller like we have in the States, as opposed to somebody in the Philippines or Korea or some place like that, you just get a feeling of confidence that you are being taken care of now, and subconsciously you maybe just slack off a little bit.
>
> Coupled with that, and their fatigue, and in my own mind I feel they were very tired, I think those two things might have sucked them right in.

The only references to descent and terrain avoidance on the crew's part in Col Pennella's discussion of the testimony and summary of the evidence were the references to regulations and procedures regarding descent and approach briefings I quoted earlier, and the statement that, "Descent procedures for aircraft arriving at McChord AFB, from the north, do not follow a set pattern."

The Issue of Fatigue:

We now inquire into the factor which may have had the most severe affect on the entire crew's ability to catch the subtle descent clearance error, especially in the context of the two items we discussed above, experience and routine. In the Safety Investigation's analysis of the facts, there was no mention at all of fatigue and in the accident investigation summary, the only reference to the fatigue factor was the following:

> Although there was some testimony indicating that the crew was probably experiencing the normal amount of fatigue associated with a flight of that duration, there was no substantial evidence that either fatigue was a major contributor to the cause of the accident or the absence of fatigue could have prevented the accident.

In this section we will again look at a fair amount of the testimony. If you are a casual reader, you may think I am beating a horse to death. I can assure you I am not. These people have a story to tell, one that just doesn't seem to get heard. As we fold in some of the testimony in detail, I want to give you an idea of what MAC missions can be like by walking you through the augmented duty days of the 40641 crew. Before we routinely toss the term 'fatigue' around, I want you to understand what this term means from an experiential level; I want to relate it to you the best I can. I want you to keep in mind the different context this sets up for the last part of the last leg of this mission. It is nothing like the context of flight simulator training, for example, where a proficient pilot gets up fresh in the morning, enters a simulator expecting the worst situations and tricks the instructor can throw at him, and then methodically and successfully catches all the wrong clearances in a well thought out and reasoned manner.

Below we will examine the typical work day, the augmented crew concept and the notion of "rest on the airplane," the schedule and its relationship to the biological clock, indications and perceptions of fatigue, and the role of fatigue in flying.

1. The Work Day: Have you ever worked a sixteen hour day -- at any kind of job? I mean like beginning work at 0600 in the morning, say, and finishing work at 2200, or 10 pm at night. And if you weren't quite done for the day your boss could extend you for an additional two hours to midnight for a total of 18 hours. And then you would get 12 hours off and do it all again, this time shifted, though, by 4 to 6 hours. And do this for several days in a row, over and over again; maybe for, say 7 to 10 days at a whack.

But you're not always so lucky to start out this routine in phase with your normal sleep schedule like this. In fact you might even start out this routine at 1900 hours or 7 pm in the evening, after of course you got a 24 to 48 hour notice, perhaps more if you're lucky, so you could "restructure your schedule of work and rest so as to report in an optimal physical state" to begin your first 16 hour day in the evening. I have had exactly such missions, not once or twice, but many times, where we left McChord at 2230 (10:30 pm) or later on Sunday evening with destination Wake Island, for example, after a refueling stop at Hickam AFB, Hawaii. Or, you might go the NORPAC route to Yokota, in which case you have to stop at Elmendorf AFB, in Anchorage, Alaska, to refuel because you're bucking the 200 knot jet stream virtually the entire way. It doesn't matter, you're facing 16-18 hours and you can't possibly get ready for it -- I've tried everything. You're going out tired, there's now way around it, and *then* you're going to work a 16-18 hour day. This is the life typical of a MAC crew member.

Maybe *you've* had a trip as a passenger to Hawaii or across the country, LA to New York or something, maybe further. You're only a passenger; were you tired at the end of the trip? Did you sleep some along the way; maybe doze off now and then? When did your trip depart? Well, that trip was only 5 or 6 hours and *you* weren't working. And it might even have been in phase with your biological clock; start in the morning, end in the late afternoon. I'm always amused when I hear some yuppy who has just completed such a trip carry on about how wiped out they are with "jet lag," seeking sympathetic ears for the woes their business imposes on them as they "jet" around the country. But it's true! It does wipe you out for a while, doesn't it!

Now consider the fact that not only are these MAC crews "working," they are flying. Mistakes don't just result in a lousy report, typo errors, pages that need to be reread again, poor arithmetic, sloppy presentations or whatever. They can cost you and your crew's lives.

But we're tough in the Air Force. We know what's expected of us and we can handle it. The mission requires it. If you don't like it, you can throw in the towel, so to speak, and just get out. It is true that some people can adapt to such schedules, and build up some tolerance to the grueling days. But we can only get so much out of our bodies and often we do not make good judgments about when that point of performance deterioration has passed. We tend to overestimate what we are capable of; besides, we simply must press on because it's our job and the mission schedule calls for it. MAC regulations specify what we're capable of doing, how much rest we need and when we need it.

Now, that's the regular ol' 16 hour day. Piece of cake! An augmented crew, which consists of an extra pilot and an extra navigator, can legally be expected to work 24 hour days with 12 hours crew rest between them. The aircraft commander does have the authority, you may recall from our earlier discussion on regulations regarding crew rest, to request additional ground time up to 24 hours if the aircrew has completed three consecutive maximum crew duty days. He can also request less than 12 hours if the mission is behind schedule. We'll discuss this decision in more detail later.

2. Augmented Crews and Rest on the Airplane: The theory of the augmented crew and the extended crew duty day is that the crew members, although all on duty, can split up the work. Those who are not actually at the work station can catch some in-flight rest. But there is a slight problem with that thinking. The rest needs to be achievable and effective in terms of recharging yourself to perform up to capability for safe flight. And it is precisely the environment and conditions under which you are supposed to get in-flight rest in order to effectively perform your flying duties that make it difficult to obtain. Although it varies among individuals, few crew members can obtain any true sleep or comfortable rest on the airplane.

Two of the crew bunks on the flight deck are 5 feet or less in length, the bottom one serving as an extra seating area in the cockpit. The third is behind the flight deck, above the cargo area -- the "hayloft." Other than that, crew members on a crowded augmented plane must use what ever can be rigged up in the cargo area, like seats which are made of woven material stretched over aluminum frames folded down on the side of the plane, if the aircraft is so configured. We're not talking about reclining airline seats here, folks. (When airline pilots augment a crew, they sit in first class and are treated accordingly.) Without exception, all locations are noisy and either too hot or too cold. If you have passengers and need to keep the heat at a point where they are comfortable down in that big empty fuselage called the cargo area, the bunk area above can be uncomfortably warm. On the flight deck, if it's too warm the pilot on duty may go to sleep, just like you in your car. It's difficult for the flight engineer to keep the heat at a comfortable level under any circumstances. In addition, you are often quite dehydrated either because of the cabin environment or because you've drank so much coffee, which is a diuretic, to keep you going on your watch.

Listen to some of the comments on in-flight rest and augmented crews from the witnesses for this accident investigation, because the investigating officer did pursue this issue. Again, some individuals feel they can do okay; others not. The first one is from a squadron Flight Examiner pilot who has been able to adjust himself to obtain some rest, but acknowledges it's an individual thing.

> Q: Are you capable of resting[114] on the 141 in flight?
>
> A: Yes I am. I know I make it a point, after a long duty day, prior to approach and landing, to get some rest.
>
> Q: When you are acting as aircraft commander, do you set some sort of a schedule for rest in the aircraft?
>
> A: No, I think that would strictly depend on the individual. If the individual felt he needed it, I make sleeping time and space available to the pilots on board, but do not require them if they feel they don't need it. If they feel they need it, then to take it.
>
> Q: The aircraft commanders you have evaluated, to your knowledge, do they do that?

114 My note: You will notice in the line of questioning here, and that which follows, that the investigating officer, by phrasing the questions in terms of 'relief away from duty' or simply 'rest,' he is implicitly, and sometimes explicitly, acknowledging that it may not really be possible to get any sleep on the airplane. Witness responses, however, usually refer to trying to get some sleep. The Air Force regulations referred to earlier do not use the word "sleep:" "An augmented crew ...is a basic crew supplemented by qualified crew members to permit in-flight rest periods." Not being able to sleep on the airplane, for whatever reason, is not at odds with this 24-hour augmented crew policy and it is evident from the framing of the questions that the investigating officer does not want to imply that actual sleep on the airplane is either needed or a factor in this accident.

A: Yes, pretty much.

Q: In an augmented crew situation, would you get more or less rest? When I say rest, I mean relief from doing a duty, a working duty on the airplane?

A: That would be difficult to assess. Again, it just depends on the size of the crew and whether people require rest.

The following is testimony from the Standardization Loadmaster, a Senior Master Sergeant, who was part of the 40641 crew, administering an evaluation ride; he stayed with the mission from McChord all the way to Yokota, just prior to the last leg, where he left the crew and went into crew rest.[115] Col Pennella's line of questioning here picks up on the relevance of in-flight crew rest to the crew's possible state of fatigue.

Q: I am thinking that individuals do have some opportunity on board a 141 to get some rest. Granted, it is not the best type of rest, but it is rest and it would at least keep you alert enough to perform you functions. Previous to the last leg of this mission, was this a normal routine with the crew to take breaks and rest?

A: On a short leg, like from Clark to Yokota, normally it wouldn't be standard to go to sleep. A short amount of sleep usually will make you groggy and maybe decrease performance. But the people that I noticed sleeping were not occupying a primary position, the two loadmasters and Lt Arensman [the 2Lt copilot].

Q: How about on that leg from Tinker to Hawaii, which is a comparable leg to the last one, about nine hours?

A: Yes sir.

Q: Did the pilots and the navigators take shift type of duties, getting some break in between their duties?

A: Right. I observed, I can't recall exactly who, but most of the crew took turns sleeping. I know that Lt Evans and Capt Eve switched off, and the navigators switched off and got some rest.

Q: Was the third pilot ever put in front of the cockpit alone the times you were there?

A: I never observed him in the seat alone, no. Additionally, I never observed him making a takeoff or a landing, he was only in the seat during inflight cruise.

Q: The two crew navigators, did they switch duties all the way through, or did the load fall on any one navigator rather than the other?

A: It looked like they switched quite evenly throughout.

Q: Do you have any difficulty sleeping on the airplane?

A: Yes.

Q: Why?

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115 We'll examine his reasons for doing this later. I will also comment here that this witness's testimony is very valuable because he was the only individual to know what was going on with the crew throughout the entire mission, until the last fateful leg from Yokota to McChord. It was extremely fortunate to have such a witness and we will examine much of his testimony later.

A: Well, noise level, heat, temperature, humidity, and probably nerves in flight.

The in-flight rest issue was also explored with other McChord witnesses. Here is some questioning of a squadron Standardization Pilot, a Captain. The context of this questioning is the fatigue issue and picks up after questions on crew rest.

Q: Also we are talking about an augmented crew. There are some facilities for rest. I am granting you that the rest is not the same as being on the ground, but do you feel that as an augmented crew you can probably go a little bit longer? It is probably a little bit easier to go to 24 hours on an augmented crew than it is to go to 16 hours as a basic crew, because as a basic crew there is no break, you can't get out of the seat, but with an augmented crew you can.[116]

A: I believe that depends on different individuals. Some people say they can sleep in the aircraft, some people claim they can't sleep in the aircraft ever. They can get out of the seat, but as far as getting to sleep, I feel that anyone knows even if you get to sleep on the aircraft, it's not like the sleep you get at home in your own bed, you just don't rest that well.

Q: Do you really think you need sleep as such, or just to get away from what you're doing, maybe just to close your eyes or to relax a little bit, get away from the headset? Is that not a form of rest also on these long days?

A: I would say it was some form of relief as far as rest goes. It all depends too on when your crew duty day started in relationship to when you awoke.

Testimony from a Standardization Flight Engineer witness, a Senior Master Sergeant, also candidly describes the difficulty of obtaining rest on the airplane. Again, in-flight sleep is not the issue being driven at by the investigator.

Q: You've been with an augmented crew where you had an opportunity to get a break -- I am not saying you would get sleep or sufficient rest, but a break?

A: Yes, that helps. So many times you have so many people on these augmented crews there is really no place to lay down. You could put 100 people on the airplane and everybody is going to be just as tired, it doesn't make any difference because they either throw so much cargo on there the only place you've got to sit is a seat downstairs or on the flight deck. When we have people downstairs, especially passengers, you have to try to keep the heat up for these people, so that the crew rest facilities is practically useless, it's so hot up there. They have never modified the plane, which they could have done years ago, to run the ducts down beneath to take the heat away from the bunks up there and put it down below. This would have been a help but it was never done.

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116 My note: Notice the framing of the questioning. It is very leading here, almost to the point that the investigator is seeking a certain flavor of response. As an aside, I cannot remember having ever been on a basic crew (two pilots, one nav) for an extended mission with long legs, during which at least one of the pilots, and usually both in their turn, did not get out of his seat and try to catch some "rest" (sleep). In fact, we always joked about it. There were always two flight engineers and two pilots, so that a flight engineer would always be at his station and a pilot or copilot would always be in the cockpit at the controls, and they could trade off with their partner to get some rest. But with only one navigator, the nav worked his butt off the entire flight taking at most a stretch and coffee break for a short while in between fixes and computer updates.

McChord crew members who were interviewed by reporters investigating circumstances surrounding the accident were also candid about the issue of augmenting crews under the assumption safety is not impacted because rest can be obtained on the plane.

Jet crash followed grueling day

Capt R. Douglas McLarty, McChord's public-information officer, noted [the 40641 crew] was an augmented crew and "crew rest was well within the (legal) limits."

But several McChord fliers took issue with the use of augmented crews as opposed to having two separate crews. In augmenting, a single crew member may be relieved by a standby member for a few hours, yet there is not a total shift of responsibility for the flight. Under regulations, the aircraft commander who pilots the plane at takeoff must be back in the driver's seat when it lands, even if he is "augmented" for rest en route.

"Augmenting is just a license to push within the legal limits," one pilot said. "It's a dead letter." The aircraft commander may catch some sleep, but it is usually "too hot and too noisy to sleep restfully like in bed," he said. [390]

Other McChord crew members, a Major navigator with about 10,000 hours flying time, 3000 of them in a C-141, and an aircraft commander, also a Major with about 7,600 hours flying time, also were outspoken in hammering home the issue of augmenting crews.

Crew sleepless 30-plus hours

Augmenting crews will not solve the fatigue problem, [the navigator] said, because sleeping accommodations aboard the C-141 are so poorly designed that no real rest is possible. This feeling was echoed by the C-141 aircraft commander.

The C141 has two bunks at the afterend of the cockpit, he said, and a third at the forward end of the cargo area. The bunks in the cockpit are short and noisy, he related, one about 4 1/2 feet long, the other about 5 feet long. The one near the cargo area is up near the heating ducts, he said. It also is noisy, and often is too hot or too cold.

"So you have a situation where you're ordered to get crew rest," he said, "and you really can't get crew rest." [391]

For calibration, it is helpful to compare these crew duty expectations with those of commercial flight crews. This inquiry was made by one of the investigative reporters.

MAC's air hours exceed commercial

The hours of work permitted air crews in a given period are greater in the Military Airlift Command (MAC) than in commercial airlines regulated by the Federal Aviation Administration, The News Tribune has learned.

An inquiry was made after some air crewmen at McChord Air Force Base contended that fatigue may have played a part in the March 20 crash of a C141 Starlifter that killed 16 persons in the Olympics.

[After explaining the basic and augmented MAC crew-duty/crew-rest policies, the article continues] ...On the other hand, commercial airlines which fly interstate are limited by FAA regulations to eight hours of flying in each 24 for an air crew. A crew further is limited to 30 hours of flying in a seven-day period, and 100 hours of flying per month.[117]

Regulations imposed by the FAA for trans-ocean flights are more liberal than those for domestic flights, but still more stringent than those set by MAC. Flying overseas, a commercial crew augmented by an additional Captain may fly for 12 hours in a 24-hour period, the FAA said. It may fly 20 hours in 40, and 24 hours in 72.

In all cases, both overseas and domestic, FAA regulations require that a crew have at least an 18-hour rest period before any duty period. However, commercial airline crews do not normally work to the maximums allowed by the FAA, an agency spokesman said. "These rarely come into play," he said, "because most crews operate under union contracts which are more stringent than these are." [392]

I believe that from the discussion above, you now have a better understanding that, irrespective of any other factors such as experience, crew rest, or mission scheduling, the basic 16 hour duty day of a MAC crew is tiring under the best of circumstances. And an augmented 24 hour duty day is pushing things to the limit, in spite of the 22nd Air Force Commander's, General Gonge's, assurance that it is just routine business. He was quoted as saying, "MAC flies with augmented crews all the time, as do commercial airlines. We have never had any problems with that." [393]

But the crew duty day is just half of the fatigue story and it is misleading, at best, to consider it in isolation. The other half has to do with scheduling and the timing of the sequence of events; that is, how crew rest fits in with the flight schedule on a trip, and how it is affected by such things as local time-zones and the length of the crew rest period. We will now take this up by examining the 40641 mission schedule and crew activities in detail. We will take the trip with the 40641 crew.

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117 My note: MAC crews are limited to 125 hours of flying in any running 30-day period. We were often against this limit and sometimes the staffing and scheduling would be so tight that an individual might "time-out" while out in the system, thus holding the crew up for a day or so until he "picked up more time" at the beginning of the running 30-day period. Again these are subject to waiver "under extraordinary conditions when life or property is in jeopardy ...by the highest authority commensurate with the demands of the situation." I am told that during the Desert Shield Operation, many crew members ran well over 200 hours for a 30-day period. There is no intention here to reflect one way or the other on the appropriateness of such policies under war-time circumstances. I am in no position to judge that; I only point it out for perspective. One MAC airplane, a C5, did crash during this mammoth airlift, killing all aboard, and Air Force spokespersons were reported to have said that crew fatigue during this airlift was definitely a concern.

3. The Schedule, the Biological Clock and the Timing of Crew Rest: Testimony from the squadron Operations Officer indicates that this was an "add-on" mission. It was received only Saturday for a Monday morning departure as an augmented mission. This required the schedulers to contact whomever they could on the weekend since the missions through the weekend and Monday had already been planned by Friday. The question was asked by Col Pennella whether this crew, in preparing for this mission violated any of the procedures that are established through regulations. The Ops Officer responded that, as far as he knew, there had been no violations of regulations.

The following actual schedule of 40641's mission (Table 9.1) was determined from the mission itinerary, testimony from the Senior Master Sergeant who was with the crew the entire trip until Yokota, estimated enroute times, and where possible, actual times reconstructed from flight plans and actual arrival and departure times logged on maintenance records. Both GMT and local times are presented and times are to the nearest 5 minutes.[118] GMT is the standard time reference to which all aviation flight records and communications refer. It is particularly convenient for discussions regarding international flight where many different local time zones are involved. The 40641 crew crossed 9 time zones in each direction of this mission.

Local times are important for human factors considerations. Based on testimony and my knowledge of MAC operations and flight crew behavior patterns, I have estimated the local times at which the crew would likely have awakened after each crew rest, assuming 8 to 9 hours of sleep. We will refer to this information later on. The cumulative awake time does not include in-flight rest periods taken by crew members en route; only that time since waking up from crew rest quarters at destination bases.

Table 9.1 MAC 40641 Actual Mission Schedule.

118 All times marked "z" refer to "zulu" or Greenwich Mean Time (GMT), 24 hour clock; for example, 0558z, 21 March 1975. Times designated with "L" indicate local time (still 24 hour clock reference); e.g. the McChord time (Pacific Daylight Time) is determined by subtracting 7 hours from GMT; so for example, 0558z, 21 March, is 2258L, 20 March, PDT.

Actual Mission Schedule for MAC 40641											
Station	Arrival		CR	Est awake hour	Alert hour	Preflt gnd time*	Departure		ETE	Cum crew duty time	Cum time awake
	GMT	Local					GMT	Local			
McChord				0545L	0645L	3:05	17/1650	17/0950 (MON)		2:05	4:05
									3:20	5:25	7:25
Tinker	17/2010	17/1510 (MON)				2:30	17/2240	17/1740 (MON)		7:55	9:55
									9:00	16:55	18:55
Hickam	18/0740	17/2140 (MON)	12	0830L	0945L	2:45	18/2230	18/1230 (TUE)		1:45	4:00
									8:45	10:30	12:45
Andersen	19/0715	19/1715 (WED)				1:50	19/0905	19/1905 (WED)		12:20	14:35
									3:50	16:10	18:25
Clark	19/1255	19/2055 (WED)	22	0800L	1900L	3:05	20/1405	20/2205 (THU)		2:05	14:05
									3:45	5:50	17:50
Yokota	20/1750	21/0250 (FRI)				2:50	20/2040	21/0540 (FRI)		8:40	20:40
									9:35	18:15	30:15
McChord	21/0615	20/2315 (THU)									
Crash	21/0558	20/2258 (THU)							9:18	18hrs	30hrs

* Includes one hour allowed to "show up;" crew duty day begins at the "show time," one hour after alert time, allowing a scheduled 2 hours and 15 minutes for flight planning and pre-flighting the airplane. If this is accomplished in less time, the crew leaves ahead of schedule.

I have extracted pertinent information from the actual mission schedules and summarized it in a "biological schedule." Times are rounded off; duration times to the half hour. In order to understand the biological ramifications of the schedule we will refer both to "site local time" and to McChord (PDT) times as the home base of initial departure, the local time for which it is assumed the crew was in biological synchronization.

Table 9.2 MAC 40641 Biological Schedule.

Crew rest site	Duration Times				Event Times						Hours of phase shift[c]
					Site Local Times			McChord Times (PDT)			
	Hrs in bed[a]	Hrs awake	Hrs on duty	Cycle hrs[b]	In bed	Wake up	Start duty	In bed	Wake up	Start duty	
McChord	8 1/2	21	17	29 1/2	2130L SUN	0600L MON	0745L MON	2130pd SUN	0600pd MON	0745pd MON	
Hickam	9	20 1/2	16	29 1/2	2330L MON	0830L TUE	1045L TUE	0230pd TUE	1130pd TUE	1345pd TUE	+5
Clark	9	30	18 1/2	39	2300L WED	0800L THU	2000L THU	0800pd WED	1700pd WED	0500pd THU	+10 1/2
McChord					2300[d] THU			2300pd THU			

[a] Assumes best case of full restful night sleep.
[b] Length of circadian cycle: Bed-time to bed-time (normal is 24 hours)
[c] Bed-time phase shift: Site bed-time less original McChord bed-time; e.g. +5 indicates 5 hours later in the day than pre-departure Sunday evening McChord bed-time.
[d] Time of crash.

This crew had a very good departure time from the McChord home base, perfectly in sync, really, with their normal routine. They got up at about 0600 and were up for 21 hours, flying two legs of 3 1/2 and 9 hours, crossing 2 time zones heading east to Tinker AFB, Oklahoma, and then 5 time zones heading west.[119] The tired crew got to bed at a relatively decent local time at Hickam AFB (Honolulu), Hawaii, of about 2330L or 11:30 at night. At that point, their circadian "day" was 29 1/2 hours, shifted +5 hours from their McChord routine, which put them in bed at the wee hours of McChord time, about 0230.

Testimony from the SMSgt Standardization Loadmaster traveling with the crew, which we will continue to refer to throughout this trip, indicated that the first day was routine but tiring.

> I noticed everyone was quite tired [at the end of the flight]. As far as I know, the entire crew went to bed early. There was no heavy drinking or partying going on.

Before going further, this is a good place (while the crew is asleep on their first night in the system) to introduce a cursory understanding of some of their biological clock processes that are being affected. [394] It is more than flight time and workload

119 This westward travel is actually only 4 time zones, but Hawaii was not on daylight savings time, whereas the continent was.

which account for the increases in fatigue experienced by crews as their trip progresses. The additional factor of biological rhythmicity must be considered. Also, the effectiveness of flight crew rest time cannot be separated from the influence of the internal biological clock either. This internal clock (there may actually be two biological clocks) programs our bodies to behave differently at different times of the day. These *circadian rhythms*[120] (*circa*, about; *dies*, day), of which there are several, are measurable and have a period of about 24 hours. They represent a complex system of such variables as body temperature, blood pressure, heart rate, sensory acuity, adrenal gland output, brain neurotransmitter levels, and even cell division. They are ubiquitous, persistent and work harmoniously in stable daily fluctuations; fluctuations which can be as much as 50% of their daily mean for some variables. Changes in these circadian variables through a normal day manifest themselves in a variety of human behaviors and performance changes. Research with experienced F-104 pilots has shown, for example, that significant rhythmic variations can be seen in overall flying performance.

The body clock is inherently capable of monitoring the passage of time, but it is flexible within a very limited range and thus requires synchronization. This synchronization is accomplished through external synchronizers or "zeitgebers" (pronounced *tsite-gay-bers*, meaning time givers), to use the German term common in the literature, that "pull along" or "entrain" the biological clock. These zeitgebers are themselves cyclic, usually with a period of 24 hours and include such natural variables as sunrise-sunset and ambient temperature, and the more important (for humans) social time cues such as interpersonal communication, work schedules, routine group activities, and artificial light.

When an individual flies from one time zone to another, his body clock and the rhythms it controls become desynchronized and must resynchronize to the local geophysical and social zeitgebers of the destination time zone. But the body rhythm system resists changes in its timing and stability. Consequently, complete resynchronization of the biological clock system can take up to several days. Research has shown, Graeber points out, that "...the impairment of well-being and performance

120 Not to be confused with the now discredited theory of "biorhythms," which refers to cycles of several days of peak and poor performance.

experienced after transmeridian flight is in large part the result of the circadian system's inability to adjust rapidly to sudden shifts in the timing of its zeitgebers. ...It is not surprising that most pilots have difficulty countering its influence." [395]

The number of time zones crossed determines the extent of phase shift and the extent of the impact; and it makes no difference whether the flight is at night or during daylight hours. Also, the response depends on the direction of travel; that is, the resynchronization rate is more rapid for westbound travel than for eastbound. This is because resynchronization after traveling west is accomplished primarily by a phase delay similar to the zeitgeber shift. The biological clock has a natural tendency to lengthen its period beyond 24 hours, and thus phase delays are more readily accommodated. The situation is quite different after eastward flight, however. Instead of advancing the biological clock to match the shortened daylength of eastward flight, many of the rhythmic variables exhibit a counter-intuititive phase delay. For example, research has shown that after crossing only 8 or 9 eastward time zones, some of the circadian rhythms adjust by lengthening their periods across 15 hours until they "lock onto" destination time zones. As a result some rhythms are advancing (e.g. adrenal hormones), while other (e.g. body temperature) are delaying to reach the same realignment with the new local zeitgebers.

These normally harmoneous rhythms which become desynchronized at different rates and directions, in effect resulting in considerable biological system disorder, affect both our physical and mental capabilities.

> Normally, when we are living at home, our circadian system resembles a finely tuned symphony, each rhythm rising and falling, not at the same time, but at its own prescribed time in harmony with one another. This internal synchronization does not persist after transmeridian flight. Even though our myriad circadian rhythms are timed by only one or two clocks, they all do not resynchronize together. Different rhythms adjust to the new zeitgebers at different rates, some lagging more than others. As a result, the jet lag which flight crews experience is symptomatic of both external desynchronization (when the timing of their circadian rhythms is not appropriate for local time) and internal desynchronization (when their readjusting internal rhythms are no longer in phase with each other). A third component is the sleep loss that results from the combined influence of both types of desynchronization. [396]

Sleep research data indicates that the duration and quality of sleep, as well as sleep pressure (the increased tendency to become tired and sleepy), differ depending on when sleep occurs within the body temperature cycle.

> Subjects sleep for longer periods when they go to sleep near the temperature peak and for much shorter periods when they retire near the temperature trough. Thus, contrary to most expectations, it is the timing of sleep, not the amount of time awake, that is the critical factor controlling sleep duration in this situation. [397]

Such rhythmic biological factors can have a significant impact on the effectiveness of crew rest and in-flight drowsiness. One implication of these research findings has to do with the timing of the onset of crew rest.

> [The findings] explain why sleep at certain body clock times can be more disturbed and less refreshing than sleep at the usual (i.e. home) body time. Conversely, they also explain why crew members sometimes report sleeping for extremely long durations after crossing several time zones. While pilots often attribute such lengthy sleeps to being excessively tired, it is likely that the timing of the sleep in relation to a crew member's altered circadian cycle helps to prolong sleep beyond its usual limit. [398]

Another implication concerns the optimal duration of layovers for obtaining crew rest.

> There is little doubt that the amount of sleep obtainable, even under ideal environmental circumstances, will depend on when sleep is attempted. If sleep is attempted when the body temperature rhythm is rising, the crew member will have considerably more difficulty getting to sleep and if successful, will usually awaken within a relatively short time. Consequently, the timing of a layover and the adequacy of the accommodations for obtaining sleep at any local time of day may be more critical than layover length for assuring proper rest before departure. [399]

Now lets wake up our crew (it's about 0830L Tuesday morning at Hickam) and head for Guam and Clark AB in the Philippines. The crew was off on the first leg to Andersen AFB, Guam by 1230L. They would fly two legs of almost 9 hours and 4 hours duration, respectively, crossing another 6 time zones. The leg to Guam was routine, but just prior to departing Guam after having refueled and taken on cargo, the Sergeant recalled, Lt Evans had commented about being tired and of having had thoughts of crew rest at Guam.

> At that point [just starting up engines] Lt Evans, the aircraft commander, made a statement that he would like to have crew rested here, which might have indicated some fatigue. ...However, I didn't notice any severe signs of fatigue at that time. I just wanted to bring that up because he did make the statement there.

One of the implications of the research mentioned above is sleep pressure, and the pattern doesn't seem to vary much with age.

> Old and young subjects fall asleep most quickly at two distinct, but remarkably consistent, times within a 24-hour period. ...They also recover from the mid-afternoon period (about 1530 hours) of maximal daytime sleepiness to reach a peak of alertness between 1930 and 2130 hours. This peak is equivalent to that exhibited at 0930 in the morning just after a night's sleep. ...This dramatic recovery is clearly spontaneous and provides strong evidence for the controlling influence of the biological clock over our underlying levels of sleepiness. [The night period of maximal sleepiness is from 0130 to 0530 hours.] [400]

In fact, this phenomenon is so pronounced, an analysis of road accidents has shown that it correlates remarkably well with road accident incidence rates. In a study done of rural single-vehicle accidents in Texas, it was found that a distinct peak occurred at 1500 hours. The accident rate rose and fell with the predicted increases and decreases in daytime sleepiness.

The time period (McChord time) when Lt Evans made the comment at Guam that he "would like to have crew rested here" corresponds with the onset of one of the two distinct time periods within a 24 hour period when maximal sleepiness occurs. He made the comment at about 1900L, or 7 pm Guam time, which was about 0200 in the morning, McChord time.[121]

In any event, the crew pressed on to Clark and ended their 20 1/2 hour day by retiring at Clark about 2300L Wednesday night (having crossed the international date line), which was now just Wednesday morning about 0800 PDT at McChord. They are now at about 10 1/2 hours of phase delay. You can now begin to see the extremes of circadian desynchronization. Their biological clock, which was on McChord time when they woke up there just 50 hours earlier, has been disrupted with very little time to adjust after crossing several time zones. If their internal clock is still even approximately close to McChord time, it is telling at least part of their circadian rhythm system that it is somewhere around 8 to 10 o'clock in the morning, the time of peak alertness. But they have been up almost 21 hours since they last slept and thus they are very tired and worn out. And finally, it is 2300L, or 11 o'clock at night locally at Clark. All the zeitgebers are pointing to the tail end of the local day. Figure 9.1 is a time line which graphically illustrates the phase shifts.

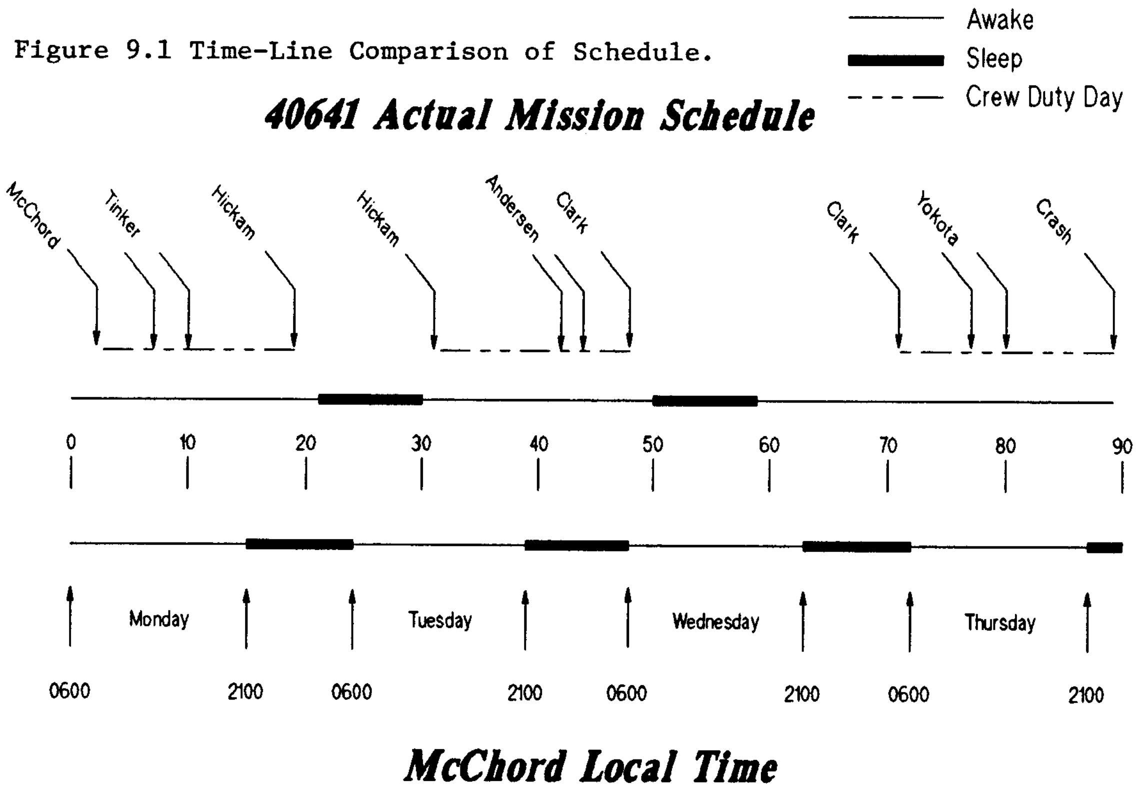
Figure 9.1 Time-Line Comparison of Mission Schedule and McChord Time.

Let's let the crew go to bed now so they can sort out their circadian dissonance in order to attempt a good night sleep, while we make a few more observations on what they're dealing with.

What I have found personally, and I have observed this to be the case with most of the crew members I have flown with, is that the local time, with all its associated zeitgebers, has the more dominant influence on what my body wants to do, at least in the short run. Arriving at Clark such that you're in bed at 2300L is really pretty good timing for a flight crew to get to sleep and stay asleep after a long day, even though that sleep may lack the quality that home sleep would have at that time. It

121 These are new insights. Other than deictic testimony about the facts, I found no such analyses of fatigue or biological clock factors in the Air Force investigations.

Figure 9.1 Time-Line Comparison of Schedule.



would be optimal, perhaps, to arrive 2 or 3 hours earlier, say between 1800 and 1900L so that you could get a good meal and relax at the Officer's Club (or NCO Club) with a beer or two before you turn in.

The worst situation with regard to crew rest is to arrive at about 0600 - 0800L. Everyone is getting up and the local scene begins to bustle with its daily activity. You're damn tired, but you really feel more like a shower and breakfast, and then perhaps some shopping or laying in the sun. It's tough to go straight to bed and expect to get a good 8 or 9 hours of decent sleep. You may get to sleep but then wake up 2 or 3 hours later feeling like hell. And it's tough to then recover some decent rest from that.

Graeber's summary of the research also points this out; that from an operational perspective it is important to realize that the timing of trips and not necessarily the length of the duty day or the number of legs flown appears to contribute more to the development of fatigue. Also, there is a positive relationship between the intensity of a day's duty and the length and quality of sleep at the end of it. That is, continued flying with only brief en route stopovers between legs is better than shorter legs with a lot of ground time. He also notes that sleep quality, although reduced on any transmeridian flight, decreases more after eastward flights than after westward flights. Flying east is simply harder on you biologically than flying west for the desynchronization reasons we discussed above. This is in the favorable direction for flying to Clark from McChord since it is 8 time zones to the west. So it appears that, as well as any situation could be for an international MAC flight crew flying the kind of long days these guys were, the 40641 crew wasn't doing too bad with respect to their schedule timing up to this point.

Unfortunately for this crew, though, we have now come upon a problem which severely compounds the fatigue situation for this mission -- the length of the crew rest period at Clark AB. The optimal length of crew rest really depends on when you arrive, that is, the local timing of the crew rest. For example, if you arrived at 1200L (noon), independent of how long a day you've just had, 12 hours of crew rest would be horrible because, for the reasons we discussed above, you would have a hard time obtaining a decent "night" sleep before you were alerted at midnight to begin another long 16 our day or more. It's afternoon when you arrive, the sun's out and everyone is about their daily activities. Clark AB is at 15° N Latitude, about the same as El Salvador, Ethiopia, Yemen, and Bangkok (Honolulu is further north at 21° N). It's tropical, hot and muggy, especially during the monsoon season.[122] When you get alerted at midnight, you may not have got much sleep.

If you arrived at, say 1800 or 1900L, however, twelve hours is just fine, because it fits your biological needs. You eat a nice meal, get the opportunity for a good night sleep and get alerted about 0600 or 0700L ready to go. See what I mean?

The absolute worst is to get a full 24 hours crew rest, unless you were to get in about 1000 to 1200L. If that were the timing, you could catch a short nap, perhaps, forcing yourself to cut it off after a couple of hours, or even forcing youself to stay up until early evening; and then go to bed expecting to start your next day at 1000 to 1200L. It's still a problem, though; 18 to 20 hours of crew rest would be much better for that arrival time.

The situation we all dreaded the most was exactly what the 40641 crew ended up with. They arrived in phase with a local time that encouraged an immediate long night sleep but were staring 24 hours in the face before their next alert. What in the

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122 The crew does get airconditioned trailers, however; complete with more cockroaches than you have ever seen in one place in your life!

hell are you going to do? You can't force yourself to stay up the first twelve hours. Nothing is open; it's just plain old black quiet night. Now maybe some nice staff scheduling officer at MAC headquarters thought he was doing this crew a favor by planning a nice long 24 hour rest period for them after two long flight days. But it probably wasn't someone experienced "out in the system," because it certainly was no favor. The crew starts the 24 hour crew rest by getting a good night sleep; getting up the next morning in phase with local time, after having finished a long 21 hour day, the previous day. Then they have to "hang out" until 2000L or 8 pm that evening before they start their grueling trip all the way to McChord, more than a quarter of the way around the globe. And guess what; right at the 8 pm show time, their biological clocks are saying: "Hey, dude; you got me up at 8 o'clock this morning after a tough day yesterday. It's 8 o'clock in the evening now; its about time for a relaxing brew and a good meal just before we hit the sack again. Come on, man, give me a break; we've just finished two 21-hour days. We're running on empty."

But, sadly, you must reply to your cantankerous biological clock: "Nope; sorry, pal. We've got to complete a 19 hour work day first." Let's check in with the Sergeant and see how the crew was doing.

> The crew arrived at billets at approximately 2200. The officers of course were billeted on the opposite end of the base, so I don't know what transpired with them. The enlisted went to the bowling alley, had a sandwich and a beer, and went to bed. I had no contact with the officers until departure time the next evening. However I did have contact with the enlisted personnel, they had a good night's sleep and were up most of the day, the next day, the 20th.
>
> Q: As far as you know, did any of them get any kind of rest just prior to the alert?
>
> A: No sir. I had a conversation with the engineers around 1600 and asked them if they had had enough rest. Sgt McGarry said he had tried to lay down and sleep but couldn't sleep. Sgt Campton hadn't slept either. So at that time I had called Ops center and decided to continue on with that crew. I asked Sgt Campton to wake me up when they got alerted. I was in a trailer right across the road, so I went to bed and got about an hour and a half sleep. We got alerted around 1900 local, our departure procedures there were normal. We did have a slight delay in a load arriving at the aircraft. I noticed Lt Evans was kind of upset at this point, the load arriving late. He wanted to get going.
>
> Q: How late was the load?
>
> A: We didn't have a late departure, but it was late in arriving, probably 40 minutes prior to departure time. There were only four pallets. However we got it on and it posed no problem and we got off.
>
> Q: And then you departed on time?
>
> A: We departed at 2203 local and the flight to Yokota was 3.7 hours. Everything was normal as far as I could tell en route. I did notice the copilot, Lt Arensman, and the two loadmasters were asleep downstairs in the cargo compartment. I slept some myself going up. They were all very tired at that time. In landing at Yokota everything was normal. Coming in the weather was rough, rain and wind. The approach was rough, a lot of turbulence, the

landing was very good. We parked the aircraft, offloading commenced at that time, I departed the aircraft with the pilots and navigators and proceeded to the Operations center where I made the determination to depart the crew and go into crew rest at Yokota.

While in the Operations center Lt Evans made a statement to the duty controller, Capt Bourgeois, that with one qualified loadmaster on the crew, since I was getting off, they wouldn't be able to carry passengers legally, without a waiver. Of course, I had told the controller I was getting off. Lt Evans joked about me flaking out. He did say he felt a sinking spell coming on himself at that time, with reference to being tired.[123]

Q: Why does having only one loadmaster require that they cannot have passengers? Is that a regulation?

A: Yes, in 55-1, flying over a normal 16-hour day requires two loadmasters on an augmented crew.

Q: You were not loadmaster augmented?

A: No. 22nd Air Force can grant a waiver to an extended duty day and I understand this happened after I departed the crew. So I can't really say, but I heard this was granted.

Lt Col Burns was in the Ops center while we were clearing in. I understood he got on the aircraft at Clark after flying in-country and back, so he was quite tired and I noticed he looked tired.

4. Indications of Fatigue: At this point the questioning began to explore specific indications of fatigue during this mission.

Q: Burns got on at Yokota?

A: No. He got on at Clark. I looked at him and I said, "Colonel, you should crew rest here, you look tired." He said, "No, I want to get home." He had planned on going on leave. That's the last I seen of the crew.

Q: Were there any other comments about fatigue by any other members of the crew that you heard?

A: I can't recall exactly.

Q: You indicated that at Clark you did not observe the officers, nor were you with the officers, during your crew rest, is that correct?

A: Right.

Q: On the leg from Clark to Yokota did you get any indication of what they had done during the day, from conversation between the pilots or any of the officers at all? Perhaps from the shopping items they may have had on board or anything of that sort?

A: I can't recall the exact conversation. The impression I had was that they had a good night's sleep, and by their appearance and by their conversation at the time, they didn't appear to have done any partying or any abuse of any type.

Q: In your opinion, do you believe that fatigue played a major factor in this accident?

A: I believe it was a factor, but not really a major factor. I think it was a factor, though.

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123 My note: From the testimony we have a pretty good indication that Lt Evans and other primary flying crew members had been up about 20 hours by this time.

At this point the questioning turned to exploring the ability to obtain rest on the airplane; testimony which I already quoted above in developing that discussion. Col Pennella began his response to the Sergeant's comment above with: "I am thinking that individuals do have some opportunity on board a 141 to get some rest." See the earlier discussion for the rest of this part of the Sergeant's testimony. Then the questioning returned to indicators of fatigue during the trip.

Q: You indicated [earlier in your testimony] at Guam that Evans said something to the effect that he would like to have crew rested at Guam?

A: Yes.

Q: What brought this on? Did he just volunteer this? Was there a discussion about fatigue at that point?

A: No sir. As I recall, they were sitting in the cockpit getting ready to leave, getting ready to start engines. I just remember the statement. I don't recall the conversation that led up to it, but I do remember he said he would like to crew rest. I think it was probably not so much fatigue but the fact that at the time of the day, it was around 1900 local, and after already having had a long day he probably felt it would have been an opportune time to crew rest and get a good meal and get a good night's sleep, rather than going on to Clark, arriving there much later, where as it did turn out nobody could get a decent meal that time of the night.

Q: You mean just a snack bar was all that was available?

A: Right.[124]

Q: In the Ops center at Yokota you indicated he [Lt Evans] said he had a sinking spell, and you also indicated you noticed that Col Burns looked tired. How did Lt Evans look?

A: Lt Evans looked all right.

Q: He didn't look tired?

A: He didn't look tired to me, but then again, he was quite young and his appearance was good. I could understand where he felt tired, because I felt tired.

Q: Did you notice any sloppiness in the procedures at all toward the end of any one of the legs or any of the flights, that might have been attributable to fatigue, or anything that was a departure from the ordinary based on fatigue?

A: No sir, I didn't. No serious deviations or even small ones in safety, or any checklist deviations or anything.

Q: Can you think of anything else that you might have that could help us in our investigations?

124 My note: Recall that when the crew arrived at Clark, they had been up about 19 hours. A good meal at the end of such a day would be on everyone's mind. Food in the Phillippines is somewhat different than you and I are used to. We used to joke in cockpit chatter coming into Clark something along the line of: "Oops; my grease low-level warning light just came on. We must be getting close to Clark." The flight-line kitchen and snack bars were the very best at putting out your "grease low-level light!" Chile-dog before bed anyone? Maybe for breakfast.

A: I feel that fatigue entered in the picture somewhere, and the schedule, the way it's laid out, is, I think, detrimental to safety. Inasmuch as the crew would have taken 15 hours at Clark instead of 24, they would have departed right after getting out of bed, and then possibly have taken 15 at Yokota, they would have been well rested out of there, and it would have extended the mission only five more hours. They had 25 hours ground time at Clark, five more would have made 30 so it would have been two 15-hour ground times at Clark and Yokota, five more hours, it would have brought them in here early in the morning.

The questioning turned briefly to Lt Evans' decisions regarding crew rest and other things, which we will examine under that general topic below. Then the questioning returned to the impact of the fatigue factor.

Q: You also indicated repeatedly that you felt, although not the major factor, fatigue was certainly a factor in the accident, and also you know that the accident, at least in part, was caused by erroneous direction from Seattle Center, right?

A: Yes sir.

Q: In you professional opinion, how do you think fatigue played into the accident? How do you think fatigue was a factor in the accident, based on what you know to have caused the accident?

A: I feel there is a certain percentage of a chance that, had they been better rested, they would have caught the mistake that the FAA controller made, and possibly an erroneous indication they may have had in their own instruments on the aircraft.

Q: You base this on the prior experience you have had as far as seeing a similar situation?

A: Not exactly a similar situation, but I base it on just knowledge of the effects of fatigue that I have experienced over the years.

Q: You indicated you had gotten off at Yokota for crew rest?

A: For crew rest and to evaluate another crew.

Q: But was this an option that you took on the crew rest? You wanted crew rest because you felt tired?

A: It was a combination of two different things. I was primarily interested in administering another evaluation rather than going the whole mission and only giving one, but in staying at Yokota crew rest was a factor. I felt tired. If an aircraft had been leaving within a couple hours I probably would have gone ahead and went to bed anyway, so I was tired.

Q: Explain this to me a little bit -- you had the option, then, to evaluate another crew coming through?

A: Yes sir.

Q: You didn't have any particular crew or airplane you were waiting on?

A: No sir.

Q: But it would be a McChord bird?

A: We arrived at the Ops center, I checked in with the controller, Col Burns and I both asked if there was any 8th Squadron or 62nd birds on the ground, Capt Bourgeois pulled out a folder, displayed a set of orders for Capt Snow and crew, said they would be leaving around 1700 the next afternoon. That is when I decided to go on crew rest and wait for them. As it turned out, I evaluated Sgt Oxier on the leg home.

Q: So your sole purpose in getting off at Yokota was not necessarily crew rest but was to evaluate another crew as well?

A: Right.[125]

Q: That is your responsibility when you are out in the system to evaluate as many loadmasters as you can?

A: Right. As far as my crew rest goes, I could have slept, my evaluation was over on Sgt Arnold, I could have slept all the way home on the aircraft. I had no inflight duties.

At this point Col Pennella asked his last question, which I already quoted, about whether the Sergeant had any difficulty sleeping on the airplane; to which he answered that he did.

5. The Role of Fatigue: Contrary to the opening quote at the beginning of this section on fatigue, which was taken from the Collateral Investigation summary of evidence, either this crew was undeniably experiencing more than "the normal amount of fatigue associated with a flight of that duration;" or, under MAC policy crews are routinely managed in a way that places them under this sort of extreme fatigue jeopardy. It would be interesting to do an historical study of crew and mission scheduling if such data were available, which I doubt that it is.

Graeber reports that, although much more research is needed and called for, the likely impact of circadian desynchronization of transmeridian flights on performance is "underscored by the consistently higher accident rate for long-haul versus short-haul commercial sectors." [401] Incredibly, at the time of his writing (1988), almost all research about the effects of multiple time zone flight on circadian rhythms, he says, has been carried out on nonpilot subjects flying as passengers. The flight crew population is different in many ways, having considerable experience in transmeridian flight for one. The perception of fatigue is different and perceiving its effects is frequently a personal experience, affected by the different types of tasks and context of expectations under which crews are operating.

While one crew member may attribute an error to fatigue, another may report a more directly perceived cause such as inattention or miscommunication. This could also result from the common belief that fatigue is not an acceptable excuse for an error because flying when tired is so much a part of the pilot profession. ...Factors [like experience] can be expected to alter the effects of transmeridian flight but not so much as to eliminate the

125 My note: Again, notice the subtle rephrasing of the Sergeant's responses. The Sergeant had just said four questions earlier, that, "If an aircraft had been leaving within a couple hours I probably would have gone ahead and went to bed anyway, so I was tired."

> incongruity between the pilot's body clock and that of the local time zone. ...Fatigue-related incidents tend to occur more frequently between midnight and 0600 hours and during the descent, approach, and landing phases of flight. [402]

The effects can be subtle. Fatigue is not something that jumps out and says, "Here I am; see what I have done to you?" This explains the difficulty of claiming it as the "cause" of an accident, in an apodeictic sense. Although there are many questions left unanswered, Graeber states,

> ...the aviation record in general indicates that poor decision making and crew coordination are considerably more responsible for accidents and unsafe incidents than are deficiencies in aircraft handling. It is therefore significant that laboratory evidence and studies on long-haul passengers have shown that time zone shifts produce significant decrements in cognitive ability and mood. [403]

Recurring drowsiness in flight affects one's attention span, ability to concentrate and perceive situations and to think them out clearly. Researchers have found, Graeber points out, that, "unless layover sleep is arranged in a satisfactory manner by an appropriate sleep-wake strategy, increased drowsiness is likely to occur during the subsequent long-haul flight." [404] In-flight naps of limited duration can help if you can get them and if you come out of them in the right sleep stage. You have the problem of the "sleep inertia" effect, that is, the tendency of falling back to sleep or of continued drowsiness with deficient cognitive functioning and lack of awareness. This phenomenon is affected by a variety of variables including the amount of prior wakefulness, the amount of sleep obtained (especially slow-wave sleep), the sleep stage awakened from, the time of day, and the type of task being performed. Graeber states that, given the relative rarity of in-flight emergencies during cruise, the sleep-inertia issue may be less significant than other things.

However, I can vividly recall a personal experience with sleep inertia and it frightened me how severe its effect was, literally rendering me non-functional with respect to my duties as a navigator. It was the second leg of one of those 16-extended-to-18 hour duty days incurred from a change in itinerary. After crew resting at Hickam, we had left for Wake Island at an odd-ball hour (I don't recall exactly what it was) and we were supposed to crew rest at Wake, and then take another plane on to Clark.[126] When we arrived, ACP said they had a plane with cargo that needed to go directly to Yokota but they had no crew coming out of crew rest to take it. Could we take the flight, they wanted to know, which would put us beyond our 16

126 Planes normally move around the system with different crews; that is, they don't normally wait for the same crew while crew resting.

hour limit and require a waiver authorization by the aircraft commander. I was not the only one who spoke up as being quite tired, but we had one of the "can-do" AC's who always goes to the limit to accomplish the mission. After polling the crew and listening to the moans and groans, he convinced us we could handle it and help these guys out. "Come on nav, I'll even take a fix for ya."

The route took us over Iwo Jima, which has a TACAN as well as a radio beacon, so about 180 miles out the 1Lt copilot said, "Nav, I've got Iwo, why don't you knock off for a bit and I'll wake you on the other side." (Our hero "we can do it, guys" aircraft commander, by the way, was asleep in the bunk.) I just crashed, so to speak, in my chair. The problem was, the copilot called me after the TACAN had broken lock on the other side, so I didn't get a fix to update my computers. The dead-reckoning computer was set with way-points in it that the autopilot was following, but it hadn't been updated (position corrected) with a fix for some time, probably 2 hours or more, since I missed the Iwo Jima fix. This meant setting up for "shooting some stars" with the sextant, I recall thinking[127], not something to be accomplished immediately. I remember him calling to me on the headset several times to wake me, each time about 10 or 15 minutes or more apart. The cockpit was still with only the copilot and flight engineer awake. Each time he would say, "Nav, I need to call in an update for the ADIZ[128]," or, "Nav, how's that update coming?" I remember answering out of a groggy stupor something like, "Okay, I'm working on it," and each time saying to myself, "God, I've got to get going on this estimate, but just a couple m o r e s e c o n d s ...of ...r e e e s t ....zzz." It was like when someone is trying to wake you up much earlier than you normally get up and you wake enough to say, "Alright, I'm getting up," just so they'll get off your back and let you sleep just a bit more, and then you're back to sleep in seconds. I was aware enough to know that I had to do a fair amount of work to get the updated estimate because I had to first get a fix and update our location. But I would just drift back to sleep as I was thinking that; not once, but several times. I finally "came to" with a start when the copilot yelled, "NAV!! Did you ever get that ETA!?!," while the flight engineer was shaking me. It was too late.

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127 The LORAN is great in that area, but I don't remember whether we were having reception problems or I just didn't think of it for a quick fix.

128 ADIZ is the Air Defense Identification Zone boundary and if you don't cross it within 5 miles either side of your filed flight course and within plus or minus 3 minutes of your most recent time estimate, you can get a violation. They can even scramble interceptors to come up and see who the hell you are, friend or foe, although this rarely happens. Nonetheless, it's kind of an important reporting point.

We had already passed the ADIZ. I didn't have too much of an idea where we were, I couldn't function well at all and by the time I could have organized a star fix, *if* I could have, we would be within TACAN range anyway.

The pilot was being woken up the same time as me to prepare for descent. After I informed the copilot I didn't have a new time estimate, and wasn't really too sure where the hell we were, he said, "Ah, that's okay. I've been faking HF radio problems with flight following. We're starting to pick up Tokyo Center on VHF now, anyway."

I think we were only off our crossing of the ADIZ by about 30 miles to one side and about 15 minutes from our flight plan time. Oh, well....

Like so many times when failures like this happen, nothing came of it. The reason this experience is so vivid in my memory is because it frightened me how totally incapable I was of performing my job. I felt bad about letting the crew down; I really wanted to get that fix and figure out where we were so I could give the copilot a good time estimate. As a navigator, I took pride in knowing where the hell we were and where we would be at any given time. But my intention didn't make any difference. I couldn't function due to sleep inertia. I didn't know that at the time; I just blamed myself for being a jerk and not getting in gear. Is it my fault we didn't do our job right and report an updated time? Maybe I should blame the copilot for forgetting to wake me up early enough to get a simple fix at Iwo (I was upset about that), or for not being persistent enough to bring me out of my coma; bucket of water probably would have done it. Or maybe we should blame the aircraft commander who was so insistent that we push on for the sake of the mission -- and then slept most of the leg. Or, maybe it's just part of a more comprehensive pattern...

Experiences with fatigue are weird. Different people perceive it and react to it in different ways. Several of the individuals who testified either tentatively brought up fatigue as a factor of concern, perhaps hedging from blaming it outright or even drawing back when pressed whether fatigue had ever impacted their performance of duties; or, they emphasized it strongly. Some of this was in response to specific questions about fatigue, but a lot of it was brought up in response to the open question, "Is there anything else you can add..." What ever the response, and however the question was framed, you will continue to get the clear impression when you read these testimonies about fatigue, as I'm sure you've gotten from earlier exerpts, that these people are telling their own stories from their own experiences in an open, honest and straightforward manner. These are the people who do this flying stuff for a living; they make careers out of it. It's how they serve their country.

One experienced squadron Standardization Navigator, a Major with over 5000 hours, tied fatigue in with the experience factor; that is, how experience helps him detect fatigue and make a prudent decision to deal with it.

Q: I am sure you are familiar with how this flight went especially from Clark to Yokota and the long day that was involved for a mission like this. Do you feel that fatigue played any kind of a factor in the cause of this accident?

A: This would be an opinion, of course, but the amount of time that they were up, I don't see how fatigue could not have been a factor, whether it was the factor or not, and that's what we've got to determine. I don't think I could make a completely positive statement that it was the factor, but anybody knows that's flown airplanes that you tend to make mistakes as you become tired, and the more tired you become the more mistakes you make and the deeper the mistakes go into your repertoire of duties. In this case it was a very serious mistake that was made. I think you would have to assume that both -- and I am speaking of navigators here -- you would have to assume that anyone who would make this mistake, if it was on the basis of fatigue, they would have to be extremely fatigued. That would be my opinion.

Q: Extremely is the word used?

A: Extremely. To give you an example, fatigued to the point of finding yourself asleep against the radar scan, and I have been in that position myself in the time I've flown 141s.

Q: Was that with an augmented crew?

A: No sir, we used to fly across the top, NORPAC, when we were able to maintain Mach .767. Frequently we would get to Elmendorf and we would need a crew duty extension to go on, we would be flying up to 18 hours by yourself, one navigator. That would probably be the time I can remember being the most tired, that and flying westbound and having an all nighttime flight, leaving here at 1130 at night and not being able to get any sleep.

Q: Do you believe you could get in that condition of exhaustion or fatigue with an augmented crew with navigators splitting the time of duty? What I am saying is, do you think you get enough rest in a 141 so you never could get in that condition described?

A: There are a lot of factors that would enter into that. I don't think that I would let myself get to that, and that is part of having flown 5000 hours. I have some signs that show up when I'm very tired and I know what these signs are. For instance, I will take a wrong time for an air position and when I see that I know I'm tired, or I will put a computer update in backwards. When I see an error like that and my feedback circuitry says you are making errors, then the 5000 hours I have flown brings up these things and you know how tired you are and you probably become aware of it, and I think this is really what we're talking about with experience. When you say somebody has a lot of experience it means they still make errors, I make errors and I'm a Standardization Navigator, but I find them before they kill me. And that is what didn't happen in this case. The person made the error and he should have had some sort of method to isolate that error and alert himself.

A squadron Flight Examiner pilot, a Captain, hedged on the fatigue issue and indicated that he wouldn't like to conjecture how it played into this accident.

Q: Do you think fatigue played a major part in the cause of this accident?

A: I can't really say whether it did or not. It would depend a lot on how they used their time in the aircraft to rest. I would say that anytime you get in an airplane and fly for a long period of time you're going to be tired. Whether that degree of fatigue impaired their judgment I can't say, not having first-hand knowledge of how they used their time in the air, whether they took time to sleep and trade off, or whether they just strapped themselves in and never got up all the way across. It would depend somewhat on that, but flying at altitude for long periods of time tends to dehydrate you and tire you out, but to what degree I can't say.

A squadron Standardization Flight Engineer, a Master Sergeant, felt fatigue is a serious issue, but did not perceive that it ever could overcome his abilities to perform his duties in a professional manner.

Q: The fatigue factor will definitely be looked at, but having flown with many crews, have you ever known them to be fatigued to such a point that it was detrimental for their approach and landing or them not acting professionally or taking shortcuts in procedures?

A: I have known crews to be exceptionally tired. I have been in this condition myself where we had a midnight or a 0300 departure from home station, where you hadn't had any sleep the prior day because you couldn't change your hours due to commitments or whatever here. You left here with a 16-hour or an 18-hour day looking you in the face, and in the end you were up in the neighborhood of 36 hours, not counting what sleep you got on the airplane, depending on what you call sleep. I have arrived over Wake Island and felt just terrible.

Q: So terrible you couldn't perform your duties?

A: No, a man always performs to the utmost of his ability, but I know I was exceptionally tired. But this is a problem that everyone had to overcome, it's a personal thing. Some people can arrange their crew rest certain ways and other people can't.

Another squadron Standardization Flight Engineer, a Senior Master Sergeant, reflected on the loss of a good crew as he made just a simple statement that reflected on how widespread the feelings were among his associates regarding fatigue.

Q: Can you think of anything else you could add that might help us in this investigation?

A: Well, of course, everybody is aware of the fact, they think fatigue probably had a lot to do with it. This has all been brought out in the accident investigation and there really isn't anything to my knowledge that hasn't already been said that I would know of. Both engineers were outstanding people. As a matter of fact, while I was on the way back from Yokota with [the Standardization Loadmaster who was with the crew earlier] we heard about this accident over the news, and we figured out who was on the crew, everbody said that was as fine a bunch as you could get together. They were well qualified, good people.

A squadron Standardization Loadmaster, an experienced Senior Master Sergeant with over 5000 hours, felt strongly about the 24 hour crew rest issue and did not hold back his thoughts on that.

Q: Can you add anything that might help in this investigation?

A: Based on my professional opinion and experience in the airplane, some 5400 hours in the C-141 here at McChord, I have flown many varied missions, primarily because this is my job as a loadmaster, and as a standardization man, to no-notice our people, to keep the quality high in the loadmaster area in the flight crews. I know from a professional approach to this, that if I landed at a base where I had maybe a 24-hour delay, or even a 20-hour delay, it was frustrating to me to get this type of release when there wasn't anything moving in the system. I'm talking about the Far East, Pacific, Southeast Asia area. It was frustrating to the point that I didn't sleep on the airplane evaluating, because my job is to evaluate, and I program myself to crew rest when I got cleared through ACP and all that, to eat, crew rest, and be ready to go fly.

Well, if I had an 18 to 24-hour delay I was dead tired, so to speak, but I had to go to bed because I had already been up evaluating and I was tired. I don't drink so therefore I don't have any party time and all that stuff. I would awaken ready to go to work, but by the time I go to work in this 24-hour period, I would be ready to fly by crew rest regulation, yes, I have already been in bed sleeping, you can only sleep so much, so therefore I am wide awake maybe some 10 or 12 hours later when we are alerted to go fly.

Now this is a personal experience of mine I have to deal with, and I am sure it has to affect other people.[129] How much, I don't know, because it depends on an individual's physical ability, but I program myself for long endurances when I go flying. When I reach my 23, 24-hour point, as authorized by the books, I go to bed and I'm ready to start again, but this is one of the things I hate, 24-hour releases, it's a bad scene, I don't like them.

Q: Do you believe fatigue may have played a major factor in this accident?

A: I can't personally say as to this accident because I was not there.

Q: On the missions you have flown similar to this one, were you fatigued to the point where you were unable to perform your duties?

A: When I get to that point, I'm finished. I say that's it. Sometimes I can reach that point even after a 16-hour day, it has a lot to do with the heat, a lot to do did I sleep well prior to the flight, because in some cases, for example in Southeast Asia, especially to me coming from the McChord area, I am acclimatized to damp, cool weather most of the time, and the heat really works on me, so therefore I have to answer in that light, that it depends.

This Flight Simulator Instructor, a Captain, related fatigue and the possibility of a pilot not drawing on his knowledge of terrain that he and every pilot at McChord knows about.

Q: Is there anything else you might add that could help in the investigation?

A: I really can't think of anything else, except that based on Lt Evans' performance with terrain clearance problems in the simulator, I personally feel that it is very possible that fatigue did have something to do with the fact that he did accept a clearance below what I would say every pilot around McChord knows to be terrain of up to almost 8,000 feet over the Olympics. This is a personal opinion but, like I said, based on his performance and my overall opinion of his terrain awareness on this approach I think it is quite possible that fatigue did have something to do with it.

A squadron Operations Officer, a Major, responded to a question regarding the schedule structure and fatigue.

Q: Looking at the mission setup, there were about three days of 16-hour or 17-hour crew duty days, well within the 55-1 regulation. Do you see that fatigue would play any major part in this accident?

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129 My note: In this and other testimony, you get the feeling that crew members are almost apologetic for a personal inadequacy; like it's their fault they can't quite measure up to the demands of "the system."

A: That would be another conjecture on my part. If the guys got in at, what, eight o'clock at night, local, at Clark, and got up the next morning at seven, eight, nine, ten o'clock in the morning, as you probably know, it's pretty hard to sleep again, so they would have been up for a good work period already before they even took off.

And finally, there is the response of a squadron Standardization pilot, a Captain, to the open-ended question. He tries to get across the biological impact of the timing of crew rest and the potential for an almost "unbearable" fatigue factor.

Q: Is there anything else you can think of you would like to add that would help this investigation?

A: As to the possibility of fatigue, I would like to make a statement in regard to the possible influence of crew fatigue in this matter. To what degree crew fatigue entered into this accident I really don't know, but I feel that some consideration ought to be given in the fact that crew fatigue may lead to mistakes, no matter what job you have, at a desk, in a car. It is a known fact that if you are in a very tired situation you may be subject to making more mistakes. In this case I assume from their long crew duty day that they probably were tired, just judging from my own experience of long duty days in a plane, I know I am probably not mentally as sharp as I would be in a less tired situation. Maybe you are more subject to making mistakes in a tired situation.

Q: Do you think, then, they were in a state of fatigue or exhaustion, that it was very definitely detrimental to the performance of their duty?

A: All I can do is judge from how I feel when I have long crew duty days in the system. I understand they had two long crew duty days and that they were given a 24-hour crew rest. It is a known fact that they were up most of the day and then they had another long crew duty day. Judging from my own situation, I think a lot of it has to do with conditioning yourself. It goes hand in hand with a lot of things, like an athlete keeping in shape by running every day. When I used to go out and fly the line as a basic aircraft commander, I don't know if I was fooling myself mentally, but I can remember when I could go out and put in fairly long crew duty days, when we were flying up to two trips a month, and I wouldn't get to the point of being as fatigued as if I would go out on a trip now and fly one long day, because about the only time I go out in the system now is when I evaluate, and if I fly like a 10-hour leg I will just be dead in regards to fatigue.

Our crew members now are not flying as frequently as they used to. Maybe this can be some factor also. I think the normal human routine is based on a 24-hour day, most people sleep on the average of eight hours a day. So in the regards to the 24-hour crew rest, with long days before and after, you get to a place and granted you get a 24-hour crew rest, and you go to sleep and your body tells you, give or take a few hours, you're going to sleep for eight hours, then you're going to be up for 16 hours before your body gets tired again. Okay, now, it's pretty hard if you are scheduled to fly at the end of that 24-hour period, to get any sleep in between the time you wake up and when you're ready to fly, because your body tells you you're not tired, whether it's daytime or nighttime. Maybe some people are more fortunate than others, they can lay down and force themselves to go to sleep, where others can't. I can't speak for anyone but myself, but I think all this should be taken into consideration.

The questioning got into Lt Evans' decision judgment regarding crew rest, which we will examine below, and into the issue of augmented crews and rest on the plane, which we covered earlier. The Captain's responses referred to getting sleep on the airplane and Col Pennella's questions probed around that issue with comments like, "Do you really think you need sleep as such, or just to get away from what you're doing...?" When the Captain responded with an "it depends," referring back to when your crew duty day started in relation to when you awoke, the questioning continued with that grant, calling for further response from the witness with regard to the need for sleep on the airplane.

> Q: Granted, the 24-hour crew rest depending on the time you get to the station, would depend on whether it's a good crew rest or not so good.
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> A: Let me say this -- I would say, for example, your sleep cycle had not been adjusted, for whatever reason, and you were alerted on a basic crew duty day of 16 hours, you were alerted at 12 o'clock at night, and I am saying that you probably hadn't been able to sleep much before you got alerted. You go out and fly the 16-hour day -- to show you what I'm getting at -- you would probably be more tired at the end of that 16 hours than if you woke up and you flew a 24-hour augmented crew duty day. Everything kind of depends on the other factors. Both of them are long crew duty days, whether basic or augmented, but all these things intermingle with each other to make one thing bearable on one end, and on the other end almost unbearable, as far as the fatigue factor goes.
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> Q: Do you believe that fatigue was a major contributing factor to this accident?
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> A: Let me put it this way -- the controller gave the wrong altitude and the crew, for some reason, I would assume didn't verify that the altitude they got was a safe altitude at that point. Now whether fatigue was a major factor in them not discovering that this was not a correct altitude I cannot say, but I feel it possibly could have been a contributing factor.

The investigative reporters found stories no different than these. One reported a navigator as saying, "If a senior navigator aboard missed the fact that they were descending over the Olympic Mountains, there must have been fatigue." [405] Another, that several crew members agreed that "fatigue probably was a contributing factor in the deaths." [406] And the story of the 40641 crew was told impassionately to the people of Tacoma, the home town of McChord, by several crew members in an article from which I have already pulled comments on the difficulty a crew member has to get rest on the airplane.

Crew sleepless 30-plus hours

The Air Force crew that smashed into a peak in the Olympic Range last week had not had any real sleep for more than 30 hours before the crash, an Air Force major has revealed.

Yet, the fatigue the crewmen must have felt is shared routinely by many Military Airlift Command fliers who criss-cross the Puget Sound area, sources have confirmed.

Sixteen men were killed March 20 when a C141 Starlifter inbound from Japan flew head-long into the side of Warrior Mountain. The crash occurred only moments after the pilot acknowledged instructions from an air controller near Seattle to descend to 5000 feet -- in an area where the minimum normally is 10,000.

Many MAC air crewmen came forward to discuss the problem after the Federal Aviation Administration announced Monday that it was a mistake by one of its controllers which had sent the ill-fated transport into the mountain. Most said they feared that all the blame for the disaster would be heaped upon the man.

"Obviously, MAC is going to hang the controller," said one air crew member, an enlisted man. "And that poor guy is probably going off his rocker. But it wasn't just the controller that caused the crash," he insisted. "He pushed the button, set it into effect. But all air crews know there's a 10,000 minimum in the Olympics, and a well-rested crew likely would have caught this error."

The ill-fated craft had carried an "augmented" crew for extended flight, including three navigators. At least one of them was a flight examiner navigator, the crewman said, and any of them plus any of the three pilots, could have spotted the mistake.

"You have to go back a long way to join this crew when they woke up for the last time in their lives," said the major, who asked not to be identified. "They had arrived at Clark in the evening hours, around eight o'clock, dead tired. They had dinner, and fell into bed."

The crew members awoke, one by one, between 7 and 10 a.m. the next day, and went out for recreation, he said. Some went swimming, others shopping.

"They were alerted then around 8 o'clock again that night," he said, "took off around midnight, and flew until daybreak."

After a brief stop in Japan, they flew on toward McChord, crossing numerous time zones and arriving over Western Washington shortly before 11 p.m., local time.

An official Air Force spokesman declined to reveal how long the crew actually had been on duty prior to the crash. His terse reply was only that the "crew duty day was well within the limits of an augmented crew."

[After explaining augmented crews, the article continues] ...Their duty day can be 24 hours long. But the latest-sleeping member of the ill-fated McChord crew already had been awake about 14 hours before becoming airborne in the Philipines, and the earliest-rising member had been awake about 17.

Another Air Force major confirmed that crew fatigue is a chronic problem in MAC. This man, a navigator, has had about 10,000 hours flying time, 3000 of them in a C141.

"Despite MAC regulations to the contrary, human beings tend to have a work-rest cycle of 16 hours awake, eight hours asleep," he said. "After a long day, when a crew is put into crew rest, they go to sleep, and eight hours later than that, they are ready for sleep again, not a 16-plus hour work day."

[The article continues to quote this Major and an experienced aircraft commander on augmented crews and the difficulty of getting sleep in the airplane, and on experience, both of which were covered under those topics above.] ...And yet another factor may have played a part in the Olympic Mountain crash, said another pilot, a man who has accumulated nearly 8,000 hours of flying time. That is the custom of many air crews to cease their own navigation once they are taken over by ground control.

"We're responsible for our own navigation, all the way in," he said. "But we never do it, and its not required."

"You can even find directives in the military where the navigator is told that as soon as he receives word the plane is under radar control, he is relieved of his responsibilities," the pilot continued. "And he's assigned other responsibilities, such as reports to write up. You wouldn't believe the number of reports we have to write."

Habit and fatigue both may have played a part, along with the controller's mistake, in last week's C141 crash, he said.

Had he ever served with an augmented crew himself? "Yes, I have, and its gruesome -- really gruesome," he said. "Can you imagine what it would be like if you were to drive from here to New York City, and instead of stopping to rest along the way you just put six more people in your car with you?" [407]

In summary, think back over all the things we have discussed regarding the cognitive framework of the crew and how the wrong clearance could not possibly have been missed because of all the training, evaluation, regulations, procedures, descent briefings that point out terrain hazards, and most importantly the professionalism of the crew. The MAC crews are superbly competent professionals; they do a remarkable job for their country.

And then think about how we might actually *expect* the clearance to be missed because of the inexperience of the crew and the routine nature of the descent and approach into McChord. Think about the sense of assurance and comfort that comes from hearing, "radar contact; fly heading 160 radar vectors to McChord," from an

American, a Washingtonian, a neighbor -- that, after you've heard nothing but foreign accents for the last 25 hours you've been in the air. And then think about the way the wrong clearance was laying there, camouflaged in the bushes -- like a quiet cobra ready to strike the bright and competent, but unsuspecting young assistant professor with the PhD in herpetology; someone who knows and respects snakes but who got just a little too close to the bush even when he knew better, who was just a little too tired at the end of a long, long day throughout which he dealt with all kinds of snakes as part of his routine.

Think about a crew which had but only two 9-hour sleeps in a period extending from 0600 Monday morning to 2300 Thursday night -- a period of over 3 1/2 days or about 90 hours. Think about a crew that had been up for the last third of that 90 hours. Think about the compounding effect of fatigue on inexperience and routine. And as you do, you cannot help but be flabbergasted and dumbfounded as you read with your own eyes how the accident investigator could just write off fatigue in a summary of the evidence with the statement:

> Although there was some testimony indicating that the crew was probably experiencing the normal amount of fatigue associated with a flight of that duration, there was no substantial evidence that either fatigue was a major contributor to the cause of the accident or the absence of fatigue could have prevented the accident.

The reaction is emotional and wrenching from the gut of those of us who have been there. It seems incomprehensible that anyone could come to such a conclusion.

Upon enlightened reflection, however, *it is totally understandable*. But before we turn to that enlightenment, I want to examine the context of Lt Evans' decisions on this trip. For we are not yet through with the development of our paradigmatic explanation of this tragedy.

The Context of Lt Evans' Decisions

There are several contextual factors surrounding the decisions that Lt Evans made throughout this mission; some very broad, some more narrow in scope. We will begin with perceptions from several of the witnesses of Lt Evans' decision-making ability; and then we'll consider some contextual factors that are not readily apparent, but which set a stage that affects decisions in subtle ways that are difficult to perceive.

Lt Evans' decision-making judgment was explored by Col Pennella in the context of the fatigue issue, as well as aircraft commander and flying decisions in general. These involved such things as following proper procedures like descent briefings, handling the crew and so forth. Would he consider his crew's input; would he be intimidated or unduely influenced by higher ranking officers, even though he was formally in charge as the aircraft commander?

The overall impression of those witnesses who were queried on the subject was favorable. In fact, the Flight Examiner, a Captain, who gave Lt Evans his initial line evaluation for aircraft commander in December, three months before the accident, related an inflight equipment failure situation and how Evans handled it. The witness also was questioned on Evans' management of the crew during descent and on his judgment regarding crew coordination. The Captain's response begins with reference to the initial AC evaluation.

> The mission left here and went to Elmendorf, Yokota, we ran at least one shuttle to Korea and back, and then back to the home station. The only thing I really remember about the line check, we had somewhat of a maintenance problem going from Osan Air Base where we were supposed to go, to Kunsan, and from there to Yokota. On descent to Kunsan one of the engineers discovered that we had low pressure in the number two hydraulic system, so he went back and checked it out, he said the pump was vibrating real bad. Lt Evans talked it over with the engineers, who were experienced in the mechanical aspects of the airplane, they probably thought it would be better if we didn't land at Kunsan and we went on to Yokota. Safety was not a factor but maintenance was a factor and there was no maintenance available at Kunsan, so Lt Evans contacted the Ops center, 22nd Operations center, told them his problem, and we orbited over Kunsan while discussing it with them, then we went back to Yokota with the maintenance problem. It seems like we did in fact declare an emergency at Yokota because the pump had started to vibrate real bad, one of the engineers recommended maybe we shut it off before it would rupture or something, so we declared an emergency and landed without number two hydraulic system, which really isn't a safety factor. But we did declare an emergency, procedurally it was the thing to do since we were in an other than normal situation. We made an uneventful safe landing at Yokota and terminated the emergency.
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> Q: Did you find Lt Evans a very competent aircraft commander?
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> A: Yes sir, I would say he was one of our competent aircraft commanders.
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> Q: Would you rate him as average, above average?
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> A: I would rate him as above average. He was excellent as far as control of the aircraft. He had a good relationship with the crew.
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> Q: Was he able to function very effectively with airmen crew-wise?
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> A: Yes sir. He also considered the crew, took their advice, listened to what they had to say before he made his decision. In fact, it was displayed very well in this instance with the hydraulics where he realized that the engineers knew more about the mechanical aspects of the aircraft than he probably did, since that is their business. He discussed it with them and got their feelings on the situation before he made the decision. He also talked it over with 22nd Command Post, so he got help from all lines before making his decision to go to Yokota instead of landing at Kunsan.

Q: Was Lt Evans the kind of aircraft commander who did everything by the book, followed procedures whether there was a Flight Examiner on board? Well, of course, you wouldn't know if he didn't do it when you weren't there, but you could tell by his proficiency if he did this normally or just for the checkride.

A: I don't have any real way of knowing exactly what he would do if I wasn't on board. I did give him another checkride when he was a copilot, as a copilot on a no-notice check while another man was getting an evaluation. He was real helpful to that person who was getting the checkride, made sure he didn't make any mistakes.

Q: In the previous flight with Lt Evans, would he be talking with the navigator in his descent, maybe not on this leg but on other legs, did he do that as a habit when you flew with him?

A: If he hadn't of I'm sure I would have caught it. I can't recall per se he did this. But if we were in a situation where I thought, while I was evaluating, if I thought we didn't have sufficient terrain clearance I certainly would have made note of it, so I can't recall that he did but I do recall that he didn't. Do you see what I mean?

Q: When you did fly with Lt Evans did he have a program of alternating in the cockpit to give his crew a chance to rest on the airplane?

A: I don't recall. We never had any really strenuous legs that we flew on that mission. We always had quite a bit of time on the ground. Probably our longest leg was the one from Elmendorf to Yokota. We had a long ground time at Elmendorf.

Q: With your limited exposure to Lt Evans, do you think if he felt that his crew was not physically capable of continuing that he would have declared crew rest in the interest of flying safety? Would he be reluctant to do something like that?

A: It is hard to say whether a guy -- to what degree fatigue would make you incapable of flying.

Q: What I am really getting at is, in your evaluation of pilots along the line you are also evaluating judgment, and this is a judgment factor where a man evaluates the capabilities of his crew, and of course it is always his prerogative to declare additional crew rest any time he feels they are unable to function efficiently.

A: Yes sir.

Q: That is what my question is directed at -- Lt Evans apparently passed his line check, his flying check, so whether you did it consciously or subconsciously, you must at some point have said, "This man is a true aircraft commander and displays good judgment."

A: Yes sir.

Q: Was Lt Evans aggressive enough that if he felt his crew was tired he would have declared crew rest?

A: Yes sir, there was no doubt of his judgment. I thought you were talking about a specific incident.

Q: Well, there might have been one where he might have declared crew rest somewhere along the line and that would have indicated the type of person he was, that he would do things like this.

A: Yes sir. [The captain indicated he understood what the Col was getting at and agreed with him, but then went into an unrelated discussion on falling into habit patterns, which we covered earlier.]

The next comments are from the squadron commander, a Lt Colonel, who would be Lt Evans' boss, so to speak, in the chain of command.

Q: Could you elaborate a little on Lt Evans' ability as a crew manager?

A: Based on my observations of Lt Evans, he would not hesitate to take whatever action he thought was necessary to make the mission operate. He's a very gregarious person, loved people, and people loved him, and if something needed saying he would say it, and by the same token, Capt Eve, although a quieter, more reserved personality, was very strong in his convictions, and had he seen that Lt Evans needed some help I am sure he would have offered it.

Q: In your mind there is no doubt that when Lt Evans launched the aircraft out of Yokota he must have been convinced that his crew was capable of handling the remainder of the mission, fatigue not being a factor?

A: I feel that if Lt Evans had thought that his crew was too fatigued to continue the mission that he would have stopped. As a matter of fact, during all of my R and C boards, I make it perfectly clear to my new aircraft commanders, new navigators, new any crew position that is being R and C'ed to the next higher level, that in the event they feel they would like to make a decision but the don't feel they would like to take the responsibility for it at that particular time, to call me, whatever time of day or night, either I or my DO[130]. So had he felt that he needed to take additional crew rest and did not feel that he might be justified, I feel certain he would have called me, and I do receive calls.

Q: Do you think the presence of two Wing navigators on board might have affected some of his decisions along the way?

A: I shouldn't think so.

There was brief reference to decision making ability by the Flight Simulator instructor, a Captain.

Q: From what you know of Lt Evans as an aircraft commander, would he have declared crew rest if he felt that the crew needed rest at Yokota?

A: Yes sir, I think he would have.

Q: Did he have enough experience and ability to be able to size up his crew on their fatigue factor at that point? What I am trying to say, does he take into consideration the rest of his crew, or does he make all the decisions himself?

A: Based on the times I have flown with him, I think he would take the rest of the crew into consideration. I don't think he would just blindly go off and make a decision.

Q: He was an individual of good judgment and conscientiousness and still mission oriented?

A: Yes sir, I believe that.

A squadron pilot who had flown with both Lt Evans and Captain Eve, in fact was Lt Evans' copilot on his line check for AC, the mission that had the hydraulic pump difficulty over Kunsan, responded to a question about Lt Evans' judgment regarding crew rest and fatigue.

Q: From your knowledge of Lt Evans and Capt Eve, were they always aware of the fatigue factor of their crews when they flew?

A: Yes, they were.

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130 Deputy Officer; R and C stands for "Review and Certification."

Q: You do believe, then, if they felt the flight would have to be conducted unsafely on that last leg from Yokota to McChord, that they would have crew rested in Yokota, if they felt the crew was tired?

A: Yes, I do.

A squadron Operations Officer, a Major, also responded positively to the judgment question on crew rest.

Q: Lt Evans was enough of an individual to have declared additional crew rest at Yokota if he felt it necessary. Was he this type of individual?

A: Yes, he was aggressive enough, I think he would take it upon himself. I would hope so.

Q: So it was his opinion at the time obviously that the crew was capable of flying the mission from the fact that he took off?

A: Yes, that is all we can say. I don't know.

The following testimony is from the Standardization Pilot, a Captain, who made extensive testimony on the fatigue issue and 24-hour crew rests.

Q: From what you know about Lt Evans as an aircraft commander, don't you think that he had the judgment, that if he felt his crew was incapable of performing the next leg of the mission he would have declared additional crew rest?[131]

A: Yes, I feel so, that's what he's an aircraft commander for.

The next two testimonies related to Evans' decisions open the door on a couple of contextual factors that we will explore further below. The first statement is that of the experienced Standardization Loadmaster, a Senior Master Sergeant, who made extensive statements on the 24-hour crew rest issue that we covered above.

Q: From what you know of Lt Evans as an aircraft commander, would he be reluctant, would his judgment be good enough to determine the fatigue factor of his crew, to determine whether they could complete the next leg of their mission?

A: I didn't know Lt Evans that well, but by working in the squadron he was mission oriented. I don't know how else I can answer that.

Q: Knowing the loadmasters on the crew, if they had difficulties with fatigue, would they have let it be known to the aircraft commander?

A: Sgt Arnold would have done that, but he was another one of those mission oriented individuals, he respected the aircraft commanders, he respected people as they were in their crew positions. This is the type of man Sgt Arnold was. Sure, he would bring things up that needed to be brought up and they would be discussed, as ACs do, but whether he did it or not, I don't know.

131 My note: The way this question is structured, only an idiot would have the lack of judgment to go on if he felt his crew was "incapable of performing the next leg." Is the investigator selectively filtering for positive information that fatigue must not have been a factor?

Q: I don't know if you are aware, but the only portion of that crew that was not augmented was the loadmaster position and they did receive a waiver because of the six passengers on board. Under the basis of that, do you think Sgt Arnold would have spoken to the aircraft commander if he was so tired that he couldn't perform?

A: I am sure he would have. I am sure they took those passengers out of the goodness of their hearts. I don't have any other comment on that because I was not there.

Q: Let me get back to Lt Evans again. From what you know about him, was he the type of individual that respected the feelings of his crew, or solicited their feelings?

A: I don't know. [This was the last response to the last question, but as the Sergeant was getting up, he added:]

Well, maybe some things have to be changed, I don't know. They should be at least entertained and looked at. This accident hurt us very bad.

The second of these two testimonies from which I am drawing specific questions regarding Lt Evans' decision making is that of a Standardization Flight Engineer, a Master Sergeant.

Q: Would Sgt McGarry have expressed his opinion to the aircraft commander if he felt he was too tired to continue on a mission, or would he have been reluctant to do so?

A: Knowing Bob, I would say he would express his opinion as far as crew rest. Now he might not press the subject, but he would say, "Well, I'm tired, how about crew rest?" Depending on what the AC thought at the time would depend on what they would do.

The last couple of quotes open the door to the *cultural context* of the tough decision faced by aircraft commanders of whether or not to proceed with the mission on schedule. We will take this up shortly. But first, for background, we know that the aircraft commander is *the* decision maker for his crew and has the final authority whether or not to put his crew on an airplane and go, or to refuse it. No one can force him to take an airplane he feels is unsafe or to proceed with a crew that is not safe. These things are spelled out in and backed by regulations. We also have seen in the testimony from the squadron commander that he is aware that young aircraft commanders, or any officers under his command, really, may feel uncomfortable with some decision situations for what ever reason, and he has opened the door for them to call for assistance in any decision they feel uncomfortable taking the responsibility for. It is a terrific statement on his part. He sounds like a hell of good CO; one who cares deeply for his crews.

From all that we have learned about Lt Evans from the testimony above, we certainly must feel good about him. He wasn't reckless. He was likable. He liked others. He was methodical and reasoned, and he solicited and acted upon input from his crew. He was a competent young man who had no difficulty handling the rigors of upgrading to AC with relatively low flying time. He was conscientious, not wishy-washy or easily intimidated. Though we know nothing of his career aspirations, he seems like a man who was motivated to do as good a job for the Air Force as he could.

This is exactly why it is important to consider the unwritten, informal, even fuzzy expectations that are part of the cultural environment of the Air Force. These are the things that mean the difference between a highly successful military career and an average career. Maybe making full "Bird" Colonel in 20 years with command responsibility, or even General beyond that, versus retiring after 20 as a Major. Promotions beyond Captain (up to Captain it's purely a time thing) and Major (which is also routine in a 20 year career but the timing varies) are based on one's cumulative record of performance as reflected in an officer's annual OER's (Officer Effectiveness Ratings) and the general perception by his CO's about his leadership capabilities.[132] Making rash, poorly judged decisions can definitely be career limiting. In fact, most all evaluations (at least at the time I was in) were so highly inflated that even any mildly constructive written criticism that might justify lowering your rating level from a "nine four" to a "nine one," say, on a 10 point scale, could seriously hurt you in the future. One "eight seven" might be an unrecoverable disaster if you had your eyes on a "bird" or a "star" down the road. Most all ratings were in the "nines" and anything lower would be perceived as "you must have really screwed up somewhere along the line." The verbal write-ups were usually so overly complementary, the standing joke was that "everyone around here walks on water -- just read it, its in our OERs."

What really makes careers is "getting the job done." Accomplishing the mission. Dedication to the mission. Showing sound command decision-making ability on the line. No one's going to be faulted for pressing on with a crew that's pretty tired. Hell, its part of the job. You don't want to be reckless, but everyone's tired, it's the way the system is. I can't imagine any crew member having the audacity to walk into the squadron commander's office after a trip and say, "The AC pushed on when I said I was tired and needed crew rest." He'd probably be told politely to think about whether or not he was cut out for this job. If there was a second time, all bets are off as to whether the person would still be flying after that.

132 My continued use of male pronouns are not intendedly sexist. In the time frame of this accident, the flying scene was all male and my comments are in that context. I am well aware that women are part of the flying scene now and I think that is an extremely positive move on the part of the Air Force.

Those who are tough enough to accomplish the mission in spite of being tired and fatigued are the ones who know how to "get the job done within the limits of safety" and they are the ones who remain part of the pool from which future commanders and drawn. No one is going to go very far if he is perceived as the guy who "always" plays it on the safe side; the one that's "always" making a big deal about safety. The one who blows the mission schedule by refusing the scheduled leg, fouling up untold other people's jobs and routines who must adjust because of your decision. Sure, maybe a rare time or two is fine if you convince several people that "some crew member wasn't physically able to do his job because he was so fatigued;" in which case ACP would try to find a replacement, like a Flight Examiner waiting for a plane, instead of blowing a mission schedule with unscheduled crew rest. Then there might even be some suspicion as to why this guy was so out of it. But having something like "doesn't hesitate to take extra crew rest for his crews when they're tired and fatigued," written in your OER isn't the stuff that makes for future commanders who, themselves, have much bigger missions to accomplish that depend on the crews accomplishing their missions and so on. This isn't right or wrong, good or bad, it just *is*. It is the cultural *context* within which all judgments and decisions are made.

Young officers who want a leadership role do not want to be perceived as "couldn't get the job done," or "couldn't make his own decision on the line; had to call the squadron commander to make it for him." It is irrelevant whether or not a specific decision got viewed that way by the CO or others, only that the young officer *thinks* is might be perceived that way. And the culture sets the stage for that perception. Why put the extra risk into your career. You want to be seen as the guy who faced up to the challenging situation, got all the input, weighed it all out, and made the right decision.

When some of the witnesses refer to Lt Evans and others as "one of those mission oriented guys," this is what they're talking about. Accomplishing the mission. Going for it. Getting the job done. It's a euphemism for "company man." Remember our discussion on background technological expectations? The same thing works here. There isn't anything wrong with it; it means sincere dedication to the job. But it has ramifications with respect to decision making that need to be considered.

Now this "finish the mission on schedule" culture isn't just perpetrated in OERs. There is peer pressure for one thing. As a crew member in any position -- nav, engineer, pilot, load -- you might make your thoughts known but you don't want to be the crew member who "forced us into crew rest, delaying the mission." You might think its great if the AC decided to go into crew rest, but there's a stigma attached, a sense that "we blew it" because of you, if you're the only one making a big deal about it. Maybe you're tired and you press that point a bit, but if it looks like you've got to be a real jerk about it to get the decision to swing your way, you'll back off instead. It's just easier to go along. You don't want ACP calling around the system announcing a mission's been delayed because the "navigator was too tired." The implication is, "what in the hell's wrong with the navigator -- did he party too much, or what?" You don't want to get even subtly ribbed back at the squadron as the guy who couldn't handle it, when the rest could have. Recall all those statements where witnesses talked about the state of being tired, that it was their *personal* problem that they had to deal with the best they could? Recall the phrasing of the questions that were structured along the lines of, "would he speak up if he felt he was too tired to complete the mission safely?" And responses like, "sure he would bring things up, but would go along with what the AC decided." Who wouldn't bring it up if they thought they were unsafe, that they couldn't physically perform their job? But if they were just really tired and fatigued? Well, where's the line? As one Sergeant indicated, a man's gotta do what a man's gotta do. You can't let fatigue get in the way of doing your job because out in the system, the job would never get done.

We're not talking about being reckless or overtly and unnecessarily jeopardizing the safety of the crew. I don't believe Lt Evans made any decisions in which he consciously felt risked the lives of his crew, let alone himself. And that is the way much of the questioning was framed by its phrasing. *Of course* he wouldn't have pressed on had he perceived the situation that way. *Of course* someone in the crew would have made a big point of it if they perceived the situation that way. It would have been extremely poor judgment for Lt Evans to have gone on if he perceived the situation that way. And we know he was the kind of guy who made sound judgments, as was Capt Eve whom he would have discussed the situation with. But *it does not* follow, even in a formal logic sense, that since we are quite certain Lt Evans was a man who made decisions based on sound judgment, a man who would not intentionally make an unsound decision, that we must not have had an unsafe situation. That we must not have had other than "the normal amount of fatigue for a trip of that length."

Perceiving fatigue (whether or not it is there and by how much) and its impact on performance, we have already brought up, is at best a dubious thing. In the culture of flying, itself, Graeber pointed out, fatigue is not really an acceptable excuse. Fatigue is part of flying. Being unsafe? No, that's not okay and all the questions that were phrased that way got the right response. 'Lt Evans would not have hesitated to go into crew rest if he felt the mission could not be carried out safely.' Unfortunately, we can't really rely on ourselves to know where that line is. That is why we shouldn't press up to where we *think* it is. Graeber writes:

> Crew members on duty are probably not able to reliably assess their own current state of fatigue and, therefore, are not aware of when they are most at risk for increased sleepiness and reduced vigilance. ...Crew members and flight operations managers should be aware of the underlying flaw in assuming that crews can monitor their own fitness for duty in this regard. [408]

It can go the other way too, Graeber notes, where crew members might not be as tired as they think they are. But with a context structured by a "go for it" culture, more often than not crews will be pushed beyond where they think they are fatigue-wise, rather than hold back short of it.

There are other aspects of the culture which affect the go or no-go decision context. Some become legendary, such as the infamous "one, two or three Colonel launch." This is the situation where a young aircraft commander gets pressured by one or more high ranking officers (i.e. full colonels) to reverse his decision to ground an airplane or delay a departure for some reason he feels is valid.

I have been on a mission or two with young ACs, First Lieutenants and Captains, where they refused to proceed with a mission until a maintenance problem was fixed; one which in their judgment was "mission essential" for one reason or another. The AC has the authority to do this, but it's not always a black and white case. Often times maintenance at the bases out in the system would respond to the write up with "could not duplicate" or "ground checked okay." Or they would "remove and replace" this box or that and sign it off. Some problems can be tricky to diagnose, for sure; however, after you've seen the same problem written up leg after leg, you begin to wonder what kind of effort they're really making to fix it.

I remember one trip in particular where the 781 maintenance log that stays with the airplane had a repeated write up on the same equipment, the radar. The same problem of weak returns, with no returns beyond 30 miles, was written up on every leg the plane flew, at least 3 or 4 times. We were at Yokota and supposed to take the bird home to McChord. Yokota maintenance had written it off with "ground check ok," but nothing had been done. This type of problem just isn't going to show up on the ground because you can't get that type of range even with a good radar on the ground. The doppler also had a history of being weak, breaking lock continually which meant your computers weren't really worth a damn because the doppler drives them with ground speed and drift. Also, it would be daytime for most of the early part of the mission and there was sun spot activity, which meant the LORAN range and effectiveness would be reduced (reception was usually better at night) and with the sun being the only celestial body out, I would only be able to get one celestial LOP (line of position). The high altitude wind chart showed the jet stream like a snake squiggling across the NORPAC route and this basically meant that DRing (dead reckoning) would be highly inaccurate. If, for example, you thought the 200+ knot wind was coming from the northwest, judging from the wind chart, and you compensated for it by putting in about a 20-25° heading correction; but the stream had shifted by the time you were at that area and it was now coming from the southwest, you would be off course be a major amount in a short period of time. And this NORPAC route takes you about 190 nm south of the Russian Kurl Islands; you know, the ones that KAL 007 flew over. So it was always comforting to see them at the edge of your radar when it was on its longest range of 210 nm.

So with a lousy doppler, no effective radar, and uncertain high speed cross winds on a day-time flight I was not interested in proceeding with the situation the way it was.[133] The AC, copilot and I discussed it thoroughly and the AC informed ACP that he wouldn't take the airplane the way it was. Well you wouldn't believe what kind of movement that brought out of the woodwork. You see, ACP doesn't want a delayed mission; and maintenance doesn't want to be charged with a delay so all the people at that base are real motivated to get the bird on its way to another base, especially home base. First out was the maintenance duty officer, a Captain, who

133 As an aside, you're always more motivated to take a plane home, so it has to feel pretty serious to refuse such a flight.

insisted we take the plane because his guys couldn't find anything wrong with the radar. Then came a "full bird" who contributed his "encouragement" to get on with the mission.

As it turned out, it resulted in a standoff. The AC held firm, cheered on by all of the crew. ACP had no other airplanes waiting to go, so we went back into crew rest, leaving a lot of people a bit "steamed." I don't remember what happened to the AC, other than that he had orders to meet with the squadron commander as soon as we arrived back at McChord.

These are the kind of things that make up the cultural context of decisions. It doesn't take too much experience out in the system to pick up on these kinds of things. Lots of stories get shared among the different crew members you fly with. Most people, especially young AC's, don't want to be in the center of that kind of conflict. So if its a gray area; well, it just makes it a lot easier all the way around if you proceed on with the mission. It's a gutsy decision to play hard-ball. You're really risking the potential of some impact on your career.

Are you beginning to see the organizational paradigm of avoidance of disorders? Can you see how information regarding safety can be subtly distorted to be more favorable than it actually is as individuals respond to the pattern of expectations that is part of the technological paradigm -- of the dominance of schedules, productivity and efficiency over safety?

When the 40641 crew arrived in Yokota with a radar they had had a history of problems with, they didn't even give maintenance a shot at fixing it. The time estimate they were given would have resulted in a recorded delay. One of the ground maintenance forms has a square titled "delay start" [time], at which time somebody's statistics sheet for their watch gets a delay tallied. Then questions get asked, "Why the delay?" and so forth. The write-up was carried as "mission essential" on the 781 when they landed at Yokota. After the crew found that fixing (or attempting to fix) the problem would take at least another hour and a half for diagnosis, and then maybe three more, worst case, to fix it, the two navigators talked it over with the AC and decided to down grade the write-up to "maintenance convenience," since there was not supposed to be any severe weather at home station. It was signed off by maintenance as C/F or "carried forward by crew" to home base.

Now, "no radar" doesn't affect the flyability of the aircraft, but it certainly is a reduction in safety margin. But, again, it's sort of gray. You can fly without it. But, then again, why take the chance? Why not just go into crew rest? Well, from the estimate maintenance gave, the tired crew would still be within their 24 hour window and would have to either complete the mission, even more tired after the maintenance delay, or go into crew rest. In fact, at the time they did get off; their crew duty day was expected to be 18 1/2 hours by the time they finished the leg home. So theoretically, since they were a legally augmented crew, they could have waited another five hours for maintenance to fix the radar and still flown the rest of the mission without taking an unscheduled crew rest. The alternative was to go into crew rest at Yokota, thus failing to complete a mission which could have been completed within their legal crew duty day. Lt Evans would then be responsible for the delay. No big deal, but if your mission oriented you'd rather get the job done as planned.

Let's dig a little deeper on this Yokota decision. First some comments about the radar problem. The Safety Investigation Analysis, which was presented earlier in the previous chapter, just described the weather at the impact site, stating it was clouds with low visibility and was not considered to be a factor in this accident. But according to a weather analysis [409], the larger weather picture was not pristine, which has implications for the decision we are examining. Although in the local McChord/Olympic Mountain vicinity there was no evidence of thunderstorm activity at the time of the crash (0600z), the general weather pattern indicated rough weather out in the gulf of Alaska. The center was only about 180 nm south of the course the crew would be flying across the gulf, at 50° N, 142° W at 0000z, moving east at about 25 knots. It was described as a large low pressure center with an occluded frontal system extending southward.[134] An extensive band of clouds preceded the frontal system to the east and the middle cloud layers would reach McChord by 0400z. A Military Weather Advisory had been issued for NW Washington by the Air Force Global Weather Central. This advisory was for isolated thunderstorms and was valid from 20/2100z to 21/0900z. The crew departed Yokota at 2040z and had an ETA McChord of 0630z. This weather system, although not directly on their course should have raised some concern for a working radar. For example, you may lose some nav aids and drift off course; the weather system may change in direction and so forth.

134 This was the same storm system that made the rescue effort so treacherous the next two days after the crash.

The forecast may be wrong! And an advisory for isolated thunderstorms for NW Washington for the period covering your arrival time is not a "no factor" situation in regards to weather radar.

Now we do have some indication that the radar might have been operable on straight and level flight, but not in banks or descent. Here is what transpired with the radar repairman, a Sergeant.

> At approximately 0315 [statement uses local times], I was dispatched to check on radar troubles on C-141 aircraft, tail number 641, which had just landed at Yokota, en route to the States. I arrived at the aircraft and read the write-ups, which were vague as to the exact trouble. Due to the plane being refueled, I was not able to work on the problem at that time, and left the plane. ...I returned at 0500, when the refueling was completed, and talked with the navigators, who were then present with the rest of the crew. Both the navigator who had been inbound and [the one who] was to be on outbound were present. They did not seem to know what was wrong, but it sounded like the radar was inoperative at anything but straight and level flight. In other words, so long as the aircraft was flying straight and level, the radar would scan ahead, but if the aircraft began a descent or turned right or left, it would probably become inoperative. This condition could have resulted from several causes, which would have taken about an hour to an hour and a half to trouble shoot. Repair could have taken as long as three hours, depending on the problem. Most likely it would have been an antenna problem. I advised the navigators of this, and they decided that they did not want to wait for the time required to trouble shoot the problem or to repair it, and they changed the form from "ME" (mission essential) to "MC" (maintenance convenience), and noted the write-up as "CF" (carried forward). They agreed to take the plane on an "as is" status, with the radar in "off" status. They so signed off on the forms, and I was never allowed to make the necessary check or repairs.
>
> While I do not, of course, know the circumstances which existed at the time of the subsequent crash of this aircraft, had the radar been functioning properly, it would, of course, have alerted the crew to the presence of mountains along their path of descent at the time they were descending for landing at McChord AFB. If it was malfunctioning as I suspect, it might not have been operational during the descent, and would have been of no help at that time. This is only an opinion, based on my experience, and what I was told by the crew as to the radar problems they were having.

The Senior Master Sergeant who was with the crew around the circuit until Yokota, where he went into crew rest, had this to say about the radar situation in response to a question about any indications of navigation equipment problems.

> I didn't know of any problems with other navigational equipment or instruments. There was a statement made after we blocked in at Yokota that, "I hope the weather is better at McChord than here because this radar set has conked out."
>
> Q: Who said that?
>
> A: I think Lt Evans said it.
>
> Q: So to the best of your knowledge this aircraft when it left Yokota was an airworthy vehicle, you only knew of some radar problems and you did not know what those difficulties were?
>
> A: No sir, I didn't know the exact difficulty with the radar at the time, but from the statement I heard I assumed it was pretty bad.

So why did Lt Evans, with his good judgment, go along with the 1Lt and Lt Col navigators instead of calling for the radar to be fixed? They certainly could have stood to have gone into crew rest and, really, this would have been a pretty good "technical excuse." Recall that the Sergeant reported a comment that Evans made about wishing they could have crew rested at Guam, but didn't. And then again that he "felt a sinking spell coming on" at Yokota, while kidding the Sergeant for "flaking out" on them. But the crew "appeared" to be okay. In answering a follow-up on how Evans looked, the Sergeant said, "He didn't look tired to me, but then again, he was quite young and his appearance was good." The Officer on duty at Yokota ACP, a Major, also said in his statement that, "The crew appeared fresh and rested to me."

The Sergeant made the following additional comments which are contextually relevant to Lt Evans' decision at Yokota to proceed on with the mission.

> Q: The 24-hour rest, I am sure, is made for the crews to kind of catch up with the supposed jet lag fatigue that is created. Of course we all know that is determined by the time you arrive at a station, whether it's a good rest or not. But as far as you know, had Lt Evans been aircraft commander enough to declare additional crew rest if he felt his crew was unable to complete the mission safely?
>
> A: I am sure if he felt conditions existed which would have interfered with safety he would have crew rested. However it is possible that they didn't feel the effects of fatigue at that point, at Yokota, as much as I did, or they may have felt it later in the flight.[135]
>
> Q: Can you make any comments about any persons of the crew, for example what I am thinking, did Lt Evans run a very shipshape crew? Did he give his people an opportunity to tell him how they felt or anything like that, as far as you know?
>
> A: I felt he done an excellent job throughout the whole mission and supervisory he done well. Capt Eve of course was giving him a buddy ride. I felt possibly Lt Evans was under a little pressure at times. He was the type person that wanted to be on time and to go, to make the mission on time. Capt Eve wasn't pressuring him or anything like that. It just appeared that he was a very dedicated person.
>
> Q: Do you believe that maybe the presence of those Wing navigators on board might have influenced Evans in making some of his decisions?
>
> A: I couldn't say. I don't believe it was. I think he would have operated the same if he had a 1st Lieutenant navigator.

So we have a picture of Lt Evans as an officer who based his decisions on sound judgment; a dedicated, mission oriented guy. He was itchy to get going at Clark when he was upset that the cargo was delayed. He was a person who wanted to be on time and to go, to make the mission happen as it was planned.

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135 My note: Recall also that the Sergeant had gotten about an hour and a half sleep before they departed, whereas the other enlisted guys were not able to.

Fatigue experienced by crews is not reliably assessable by the very ones who are on duty; further, there is a cultural tendency to discount it's significance. Thus crew members are not aware of the state of risk they enter as fatigue progresses. Assuming that crew members *can* reliably monitor their own fitness for duty in this regard is fraught with this underlying flaw.

There was plenty of evidence that this crew was extremely fatigued. Subtle indicators were overlooked. Recall the testimony from the experienced flight examiner navigator with several thousand hours; he said it takes a lot of experience to know those subtle cues and he gave some examples. Maintenance decisions regarding the proper diagnosis and repair of equipment lacked prudence. The decision to go was an unmitigated disaster.

More on Organizational Context and the MAC Safety Climate

We have discussed much under the general heading of "Cognitive Framework of the Crew." We continue here to broaden our consideration of the safety climate under which these MAC flights operate. In particular, we will expand on the organizational paradigm that was pointed to already; of avoidance of disorder and its implications for distortion of information and subsequent perspectives regarding flight safety in MAC. We will consider some examples of specific actions which illustrate the paradigm further. Finally, we will consider this distortion in the context of this actual accident investigation.

The MAC Safety Climate: Formal Organizational Policy

To begin, let us reflect on the importance of safety in MAC. Safety in MAC, just like it is in NASA and other aviation organizations, is essential for the sustained and successful accomplishment of its mission. It is not just some nicety on the side; a bone we throw to the crews who risk their lives for their country. It is a core, central element of the mission. It is given serious consideration and formal recognition beginning with basic pilot and navigator training, on through any aircraft type upgrades and continued training and evaluation at the aviator's home base. It is concretely and forcefully spelled out in the regulations and procedures of the Major Command; the formal policies and goals. MAC Regulation 55-1 states the following under the heading of "Airlift Operations Policies:"

> **Command Responsibility and Authority.** The mission of MAC will be based on the concept that safety comes first. The MAC accident prevention goal is elimination of all preventable accidents. Calculated risks in MAC operations will not be condoned. MAC commanders will enforce a basic policy of safety in all airlift operations. Essential elements of safety include quality condition of equipment meticulously inspected before flight, thorough training and motivation of aircrew and support personnel, scrupulous attention to duty, good judgment, sound operational planning, and efficient use of resources.
>
> **Use of Augmented Airlift Aircrews.** Normally, augmented airlift aircrews will not be used.
>
> **Crew Rest.** MAC AF commanders should establish ground times in excess of 15 hours at designated en route stations to provide aircrews, flying several consecutive days away from home station, the opportunity to overcome the cumulative effects of fatigue.
>
> The aircraft commander is authorized to modify normal ground time when: (a) It is in the interest of safety. (b) The mission is behind schedule. He may request less than 15 hours ground time prior to beginning crew rest. The crew will not report for a flight until at least 12 hours have elapsed since termination of the previous crew duty period. ACP will not request the aircraft commander to accept less than 15 hours. (c) The aircrew has completed three consecutive maximum crew duty days. The aircraft commander will normally declare additional ground time up to 24 hours. ACP will not request him to accept less than 24 hours. At stage locations, aircrew position in the stage will be determined by projected alert time, and not on first-in, first-out basis.

And MAC supplements to Air Force Regulations, AFR 60-16/MACSUP 1, state:

> When a flight is planned outside the control areas, the pilot in command or designated crew member will consult appropriate maps/charts to determine the minimum safe altitude (minimum sector/emergency safe altitude, as applicable). Special attention will be given to obstacles and contour lines as well as spot elevations, to determine terrain/obstacle elevations for the proposed flight route. ...Prior to descent from cruise altitude, the pilot will brief on and insure the crew understands the applicable minimum altitude/terrain clearance requirements for the expected route of flight... During descent, the pilot will insure that the altitude he accepts will provide adequate terrain clearance. The copilot and navigator, if applicable, will assist the pilot by referring to appropriate FLIP documents and maps/charts. ...The importance of accurate en route and terminal position fixing cannot be overemphasized. All available navigation aids should be used.

Safety is formally agreed upon and understood by all of those who are associated with flying. It is part of the flying culture. Everyone in MAC, in the Air Force for that matter, is concerned with safety. Even the brass have virtually all been professional fliers themselves earlier in their careers. No commander at any level would believe he is doing anything that would unnecessarily impact flying safety in a negative way. It would be absurd to believe that they didn't care about the safety and well being of their young crews. But it would not be absurd for them not to recognize that they can succumb, just like most any normal individual, to the technological paradigm and the paradigm of avoidance of disorder and distortion of information.

The MAC Safety Climate: Organizational Reality -- Avoidance of Disorder

When we examine flight safety paradigmatically we can see patterns that explain the condition of flight safety. We can see patterns, recurring patterns which reflect an erosion of this profound formal commitment we believe we have to flight safety. We can understand what is happening if we are guided by an understanding of the paradigms that underlie flight safety. If we reflect on the technological paradigm, the pattern of the device whose progress is measured by increased availability of the service or commodity it procures. Of the importance of the background expectations we all buy into which promote ever more instantaneous and ubiquitous availability of the end commodity. Of efficiency and the dominance, the economic dominance, of the primary elements of availability which are directly and tangibly experienced, over safety which is only experienced in its failure.

And we can understand the erosion pressures on flight safety better if we understand the selective filtering out of unfavorable information to the organizational complex. Of unfavorable information regarding flight safety as organizational complexes follow their natural patterns of avoiding disorder, in spite of formally stated goals and policies. We can understand this erosion pressure, the pressure to chew into safety margin to serve the other ever present aspects of availability; how it becomes ever more ominous when safety failures are themselves relatively rare events.

We can also understand that adjustments can be made in favor of safety when sufficient disorder is created which causes the system to adapt to it. We know that the rare physical disruptions, that is accidents, lead to significant disorder that results in (attempts, at least for) safety improvements. We have seen that just recently with the two ground incursion accidents at Detroit and Los Angeles that have left more blood on the runway. Ground safety is now receiving a prioroity it never could command before.

But there are other mechanisms for disorder that do not rely on physical disasters. Methods of causing disorder so that organizational complexes will adapt with favorable responses toward safety. Unfortunately, these are constantly subjected to the erosion forces of the paradigms I mentioned.

One of these mechanisms for non-physically caused disorder is to discuss safety issues in a variety of open formats. It helps refresh and expand our cognitive framework as we try to understand what flight safety is all about. Public comments such as those made by McChord crew members to reporters in the wake of the 40641 tragedy was not only a response to the disorder caused by the physical accident -- they were disorder generating in and of themselves. We will see this illustrated below. Another mechanism is through formal safety reporting channels, the currently most well known of which is the ASRS, the Aviation Safety Reporting System. It is a system, as I have pointed out earlier, designed to protect the identity of individuals who report unsafe occurrences such that others may learn from candid and open responses, and take action where indicated. And this system thrives today in commercial aviation.

The Air Force had a system (I don't know the current status of it) so that aircrew members could report operational safety problems. These were called Operational Hazard Reports or OHR's. Recall when we were discussing what might have resulted if the 40641 crew had caught the controller's error by coming back with a probe like, "Seattle, was that clearance for 40641?" where upon a typical response might have been, "Negative 641, maintain 10,000; Navy 28323 descend and maintain 5000." Of course, they would have continued on in with a standard approach and landed within 15 minutes. Now, since there was a wrong clearance, the AC (or any crew member for that matter) could have written up an OHR on the controller.

But he probably would not have. Why? Well, first of all it takes paper work which crews despise, especially tired crews who just want to get home. Secondly, controllers and pilots share a culture context. They're partners in a common activity called flying. Few pilots probably ever know or even meet controllers personally, but they talk to them all the time and there's a friendliness about it. If there was a mistaken communication that did not have near serious results, i.e. it was caught quickly -- well, we all make mistakes and the pilots and controllers are sort of a team. There's a feeling that you're really screwing the guy on the ground if you wright up an OHR for a minor mistake. So how serious was the mistake?

Well, *if they had caught it* and it was clarified immediately, it probably wouldn't have been considered a big enough deal to "screw over" some poor guy just trying to do his job on the ground -- a job, I might add, that is known to be tough and is highly respected by all those who fly for a living. Those are the guys who keep us out of trouble in heavy traffic. Recall the Flight Simulator Instructor's comments on Lt

Evans when he caught a wrong clearance in the simulator that would have taken them down amongst terrain hazards. He said to his copilot (operator of the radio) in textbook fashion, "No, tell them we can't go that low, the minimum en route altitude here is higher than that, we will maintain the minimum en route altitude." He didn't comment that the son-of-a-bitch who gave them the clearance might have killed them with it; that it was a serious safety violation and we ought to write an OHR on him.

As it was, sadly, the 40641 crew *didn't catch it* and they died. So short a separation in one's mind between a perception of "no big deal, lets just get home," and death for 16 people along with the destruction of a controller's career.

In my flying experience, I have encountered many more situations, wrong clearances, other safety related events and so forth, in which OHR's were clearly appropriate but were not written up, than similar situations where one was written. I remember talking it over amongst the pilot, copilot and nav, and consciously thinking about whether or not we should write one on this controller who made an error in his directive to us, and then deciding not to be "assholes," unless it was a really flagrant violation of safety. It depends on the individual; some people see it as a conviction, the only real way of keeping the safety climate adjusted and responsive to unsafe conditions. Others see it as an extra hassle that, in fact, might make you feel some guilt for "sticking it" to someone. Such is the culture.

Another reason there may be a tendency not to be especially concerned with pointing out safety infractions or unsafe conditions is the same very reason *for* pointing them out -- it causes disorder in the organizational complex. That makes things uncomfortable for people; lots of people have to make adjustments and so forth. It can be easier just to dampen out the source of the disorder -- the person or persons causing the disorder. And when that happens, obviously there is a distortion of information with respect to the safety climate.

With this background in mind, I want to present some additional illustrations of what I have been talking about: the paradigmatic erosion of flight safety.

The first is an article which lays out comments made by several crew members in the wake of the McChord accident. Again, these are people in the business who want to tell their stories from their own experiences.

Air Force pressuring 'wave-making' flight personnel

McCHORD AFB -- "Everybody walks around with water right up under their nose," said an Air Force officer here.

"If somebody starts making waves, they look around and see which way the waves are coming from. Then, they walk slowly over there and hold his head under water until the bubbles stop."

That is what happens to some people who ripple the water by calling attention to Air Force safety hazards, the officer said.

Violations of safety regulations are commonplace in the Military Airlift Command, air crewmen have told The News Tribune, yet efforts to put a stop to them can destroy a man's career. The observations were voiced by crewmen concerned at the possibility of more crashes like the one in the Olympic Mountains last week which claimed 16 lives.

One man, an aircraft commander with the rank of Major, has been grounded for writing up too many "Operational Hazard Reports," sources said, and has been referred to an Air Force psychiatrist here for examination.

In one of his reports, the major had criticized a two star general, the sources said, after the general tried to order him to make a trans-Atlantic flight without navigational equipment.

The major, described by an instructor-pilot as "one of the best pilots I've ever flown with," had been en route from Salina, Kansas, to Stuttgart, Germany, with nearly 100 Army troops aboard his C141. His navigating equipment malfunctioned near the U.S. East Coast.

When the major set down at an East Coast air base, and grounded his plane, the General there ordered him to continue his mission despite the malfunction, sources said.

The major refused, his aircraft was repaired, and he wrote up the General as an "operational hazard" when he finished the flight.

Then the major's commander told him not to write any more hazard reports, the source said. And when he did, the commander sent him to the flight surgeon, who grounded the man.

"I feel the only tool the pilot has to communicate with the upper management is our operational hazard report," said another McChord pilot, also a major.

"But as a result of some of the hazard reports that I've written, I've gotten into trouble. I've got a whole (briefcase) full of hazard reports that have been rejected, or not acted upon." [410]

An article almost three years later told of the harassment of two Air Force C-141 pilots for alleging safety violations.

Rep. Dicks wants full probe at McChord

Congressman Norm Dicks has asked the Air Force for a "full investigation" into allegations by two former McChord Air Force Base pilots who complained of lax safety and improper personnel procedures.

One of those two is a former C-141 transport pilot ...who was grounded and kicked out of the service, he says, because the Air Force has no room in its ranks for those who criticize procedures.

The other, another C-141 pilot remained unnamed by Dick's office at his request.

Barrie Jackson, Dicks' chief administrative aide, said he already has had two meetings, one seven hours long, with Air Force congressional liaison officers regarding the cases.

Those officers, he said, expect the investigations to consume at least two months.

[The pilot who was kicked out] contends the Air Force attempted to have him removed from the service by trumping up charges that he was mentally unbalanced.

The 40-year-old former Air Force Major claims that a score of hazard reports he submitted regarding unsafe and uneconomical Air Force procedures were disregarded by Air Force higher-ups who were concerned chiefly with their own advancement.

[The pilot] had predicted in one of those reports that a transport aircraft inbound to McChord over the Olympic Mountains could crash because crews weren't rested and charts weren't sufficiently detailed.

Such an accident happened in March 1975 when one of the giant transport aircraft crashed into Mount Constance on a nighttime approach to McChord. [411]

To continue with the "Air Force pressuring 'wave-making' flight personnel' article:

The pressure to fly an unsafe aircraft can become intense, reported one air crewman, a navigator. He said the reason is that maintenance officers' efficiency reports are based on "delay rates," rather than on safety of aircraft.

"The obvious results are what air crews call 'two, three or four-Colonel departures,'" he said, "involving maintenance officers, wing duty officers and operations center people doing everything possible to push an aircrew into an on-time takeoff. Everything except fixing the aircraft."

He cited a recent flight of nearly a week, in which some of the aircraft's electrical gear malfunctioned the first day. Throughout the trip, the crew tried to get it repaired, he said, but at each stop the maintenance crews failed to fix it.

In another case, an air crewman reported, his aircraft was being dispatched with a load consisting of two large forklifts.

"They were loaded incorrectly - mispositioned in the aircraft - and they did not have the right type or quantity of load spreaders placed beneath the wheels," he said. "The aircraft commander refused to fly the aircraft until it was corrected."

Someone summoned a Colonel in from the golf course course, a source related. The Colonel, in civilian clothes, drove his civilian car onto the flight line and stormed aboard the plane.

He twice asked the aircraft commander, a Reservist, if he would fly the craft the way it was, the crewmember reported. And twice, the commander said he would not.

"So the Colonel told the commander to get his Reserve crew off the airplane," the crewmember related. "He said he was going to put an active duty crew aboard and send it out."

Another man picked up the story.

"When he found he couldn't intimidate the Captain, he drove in to the command center, which briefed him on the whole situation," the man said. "The Captain inside it said, 'Colonel, the guy's right. He can't fly that airplane the way it is.'"

"Whereupon the Colonel returns to the airplane and says, 'I'm sorry, Captain, it will be changed.'"

"Twenty minutes later they were on their way." [412]

The 40641 accident caused a major disorder in the local McChord community and the base's higher commands. Actions to control the disorder were taken at all levels as these articles indicate. This one is from crew member sources.

AF puts lid on news

"The gumshoes are running all over, and the word is out," a McChord-based crewman said Thursday. "Anyone caught talking to a newspaper reporter will be fired."

To be "fired" for a regular Air Force officer means to be transferred to an insignificant position, he said. For a Reserve Officer, it means transfer to inactive status.

The orders were issued Thursday by the commanders of the regular and reserve Wings at McChord, he said. [413]

This next article is based on official Air Force sources.

Air Force admits zippered-lip rule

The Air Force has zippered the lips of all airmen who might comment on last week's plane accident that cost 16 lives, a spokesman admitted today.

"While the crash is under investigation a blackout is placed on anything that could be brought into the investigation," Capt R. Douglas McLarty, McChord Air Force Base information officer, said.

He said a 12-man investigative team should take several weeks to reach its conclusions.

"By Air Force regulations, I am not allowed to comment on events surrounding the accident," the officer said. "Nobody else is, either!"

Capt McLarty denied a report that copies of Thursday's News Tribune were removed officially from base newsstands.

"I guess they were just bought up in a hurry," he said. "No one removed the paper. It was news about McChord -- front-page stuff."

"This is a free country, and we have free speech. The clamps will be off when the investigation is complete. The investigative board will come out with a statement on its conclusions."136

"Then people's opinions, speculations, maybes and 'when I was flying' stories can be told. But while the Air Force is conducting an investigation, people are not permitted to comment."

Capt. McLarty said however, "I don't think there is a penalty" that would be imposed on an airman's talking with the press. And he denied that any such action had been threatened.

As to the accident, he said, "I wasn't there. You weren't up in that airplane. No one knows what really happened."

"I think it's a shame about these stories. We had an accident. Emotions are high. This is not unusual when accidents happen."

"It just seems wrong to take comments by people, to take stories full of wild answers, 'may-have-happeneds,' personal opinions, speculations and innuendoes from people who may not have the full story -- then slam these all over the newspapers. Oh, I'm sure it sells papers."

Capt McLarty indicated there will be cooperation. "If somebody would call up from the TNT and say, 'We want to see airplanes and talk to crew members' -- as long as it didn't involve this accident -- no sweat," he said.

"I'm really disappointed. I just feel kind of bad about the publicity. These comments about a news lid, and gumshoes running around -- if you understand the regulations -- commanders have to reiterate the regulations.

"Maybe somebody just took the ball and ran with it." [414]

This article is a congressional response to the reluctance of the Air Force to release information to reporters.

Crash report secrecy:
Magnuson wants 'legal justification'

Sen. Warren Magnuson (D-Wash.) has told the Air Force he will want its "legal justification" if it does not plan to make a full public report on reasons for the March 20 crash of one of its C141s in the Olympic Mountains.

That development came Tuesday in a letter from Magnuson to John L. McLucas, Secretary of the Air Force.

Magnuson wrote the letter after a Military Airlift Command spokesman at Scott Air Force Base, Ill., told newsmen that a report on the crash investigation, when completed, would be "not releasable," but that a "statement of circumstances can possibly be released..." [415]

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136 My note: This, obviously was a false statement, but, giving the information officer benefit of the doubt, he may not have understood safety and accident investigation policy.

One of the more poignant examples that illustrates the paradigmatic nature of this situation, is that of an Air Force Colonel who stood up for his men. It is the story of Colonel Thomas E. Schaefer, who was McChord's Deputy Commander for Operations. The following articles deal with the situation surrounding his demise. The first three are from different sources so they each give a bit of a different perspective on what the actually wording of the exchange was, but the message is quite clear in all cases. One article titled, "General's remarks on jet crash stir furor at McChord," goes into a fair amount of depth on the meeting with follow-up interviews with crew members, a lot of which I have already quoted. There was a brief reference to the exchange. "...A member of the audience packed into the 500-seat Base Theater said it was an 'unbelievable scene.' One source said Gonge 'had his facts screwed up' and members of the audience stood up and politely corrected him. Finally a senior officer told him the same." [416] The other articles paint a more vigorous happening.

Airmen charge fatigue danger

McChord AFB -- A plane load of men had crashed on a mountain, and in the aftermath of the tragedy, a confrontation -- of sorts -- developed here between the men who fly and the men who order them to fly.

A General was embarrassed, a Colonel was outraged, and another Colonel lost his job.

It happened in the base theater last Friday, when several hundred air crewmen indicated they thought it was dangerous to push Military Airlift Command crews to the point of fatigue.

Fatigue was, some of them said, probably a contributing factor in the deaths March 20 of the 16 men whose MAC transport rammed a mountain in the Olympic Range.

...An air crewman who attended the meeting described it this way:

"[The General] came in, and said the airplane had been found about the 6000-foot level of Warrior Mountain. And he said the (Federal Aviation Administration) center had advised that, on a playback of tapes, it found out a controller had given instructions meant for a Navy A4 to the MAC bird, and the pilot didn't catch it (the mistake).

"Then he continued to say that this was goof No. 1. Goof No. 2 was that the pilot had acknowledged this clearance. The general then said what he was going to do to preclude this in the future, such as putting a navigator on every flight.

"But the good part of the meeting came a few minutes later. He said, 'Do you have any questions, or any suggestions how a recurrence of something like this can be avoided?'"

Several crewmen arose, the observer said, and asked how long the crew on the fatal flight had gone without proper sleep before the crash.

Then Col Thomas E. Schaefer stood up. He was -- at the time -- McChord's deputy commander for operations.

The observer continued: "Col Schaefer said, 'The point these people are trying to make, General, is that that crew had been up 26 f---ing hours before they hit the hill.'"

"That's when everybody applauded."

The General left soon afterward, the observer said, and Col. Edward J. Nash took the floor. Nash is commander of the 62nd Military Airlift Wing here.

He told his men they had acted in "an unprofessional and immature manner," the observer recounted.

On Monday, the 44-year-old Schaefer was replaced by Col Daniel J. Rehm, who came here from Travis.

"Col Schaefer is on leave right now," and official Air Force spokesman said. "He has yet to get an assignment."

"We're all behind that man," one enlisted air crew member said later. "He's the only one who had the guts to stand up and say something."

"Schaefer won the battle," said another. "But he lost the war." [417]

Colonel rumored 'fired' in clash over jet crew's rest

Was a full colonel relieved of duty for speaking out against a two-star general in the aftermath of the fatal C-141 Starlifter crash?

The general, Maj Gen John F. Gonge, commander of the 22nd Air Force, says "no."

Subordinates of Col Thomas E. Schaefer, 44, insist "yes."

Schaefer, described by some subordinate officers as "bright, popular and likely to have gone on to general's rank," corrected Gonge at a heated meeting at McChord Air Force Base last Friday.

Gonge said that the crew of the ill-fated C-141 had had 24-hour crew rest at Yokota, Tokyo, before flying nonstop to McChord. The plane crashed in the Olympics just minutes away from McChord.

Several members of the audience of the packed 500-seat Base Theater stood up and said politely, "Sir, they were on the ground (at Yokota) only 3 hours." Witnesses said Gonge did not accept that.

Finally, Schaefer, McChord's deputy commander for operations, stood up and told Gonge, "Sir, you've got your facts wrong. These men are right."

Monday Schaefer was "fired" from his job, the Air Force terminology for being relieved of duty and to be reassigned some other job. Col Daniel J. Rehm of Travis Air Force Base, Calif., was assigned to Schaefer's job.

Subordinates say it was for speaking up.

Gonge, in a statement to The Times, denied he fired Schaefer for speaking up.

"He was relieved from his job not for what he said there," Gonge said. "He was relieved for not following MAC (Military Airlift Command) policy and it refers to matters predating this accident."

Schaefer was reported on leave and could not be reached for comment. [418]

Col Thomas E. Schaefer is now a legendary figure among the crew members at McChord. A young Captain, a pilot who would have been in grade school when this incident occurred, told me recently that several of the guys wondered what ever happened to that Colonel who stood up to the General on behalf of his crews in that Base-wide meeting. The following article that came out six weeks after the Base Theater meeting, indicates what happened to him immediately after he was relieved from his McChord duties.

Colonel who spoke out given transfer

McCHORD AFB -- Col Thomas E. Schaefer, the man who stood up and told a general that crew fatigue may have helped cause a fatal crash in the Olympics March 20, has received his walking papers.

He is being transferred to North Dakota.

Schaefer's exchange with the General occurred March 21, one day after a McChord-bound C141 Starlifter smashed into a mountain in the Olympic range, killing 16 men.

Maj Gen John F. Gonge, commander of the 22nd Air Force, of which McChord squadrons are a part, had called a meeting of air crews at the base theater here.

Gonge criticized the dead aircraft crew, witnesses said later, and some crewmen at the meeting arose and asked how long the victims had gone without proper sleep before the crash.

Then Schaefer stood up. An observer described his remarks this way:

"Col Schaefer said, 'The point these people are trying to make, General, is that the air crew had been up 26 f---ing hours before they hit the hill.'"

"That's when everybody applauded."

That was on a Friday. On Monday, the 44-year-old Schaefer was relieved of his duties as McChord's deputy commander for operations and replaced by Col Daniel J. Rehm of Travis AFB.

Schaefer went on leave. He had no regular job here when he returned and was working, an Air Force spokesman said, as "special assistant to the McChord commander."

Schaefer's permanent orders finally were cut, the spokesman said today, and he will be division director of operation for the 57th Air Division, a Strategic Air Command unit at Minot Air Force Base.

He is expected to leave here by June. [419]

Well I want to tell you about Minot as an assignment. First of all, among just about anybody I've ever known who wasn't in SAC, and among a lot of those who were, any assignment in SAC, flying or not, was considered a genuine dog.[137] You pulled a lot of "alert time" just sitting on the pad waiting for Russians to start a nuclear attack. The missle silo jobs were even worse. The KC-135 tankers were under powered and, full of fuel, were thought of as a runway bomb with four engines on it. The B-52s were old as the hills and were called BUF's, for "Big Ugly Fuckers" (what you usually see in print is "Big Ugly Fellows," but that's only for public consumption!). And Minot, North Dakota, excuse me for being blunt, was considered to be one of the truly bum locations a person could draw duty in the Air Force. It's on par with Thule, Greenland; it' known as a "state-side remote" assignment.

But the real irony was discovered by these young fellows currently at McChord who wondered about this legendary Col Schaefer. The Captain told me that they had dug around and found that, after his stint at Minot, Schaefer was sent to Iran on embassy duty and became one of the several hundred hostages held for four hundred some-odd days. It is unkown what Schaefer is up to these days.

The 40641 Air Force Investigations: Avoidance of Disorder and the Distortion of Information

Finally, what about distortion of information in the 40641 Safety and Accident Investigations? Well, we don't know what the "findings" were, for that information is not publically available. We do know, however, that the Board's analysis of the facts in the Safety Investigation point apodeictically to the controller's error as the cause of this accident.

137 Sorry SAC guys and North Dakotans, no offense intended. I've just got to tell it like it is.

We have none of the testimony given before the Safety Board. But, we have all of the testimony given before the Investigating Officer of the Collateral Accident Investigation, Col Pennella. It would be safe to assume the set of witnesses for both investigations would be largely the same, judging from the organizational and flight roles of those who testified in Col Pennella's investigation. In fact the Safety Board passes on a list of its witnesses to the Collateral Investigator. It would also be safe to assume that in front of the Safety Board, with guaranteed confidentiality and immunity, the witnesses would be even more forthcoming, if not just as candid as they were under sworn testimony, after having been read their constitutional rights in front of Col Pennella. I found those testimonies, which I have used extensively to make my points, as being open, candid, and forthright overall. Thus, I don't think we are missing much from the Safety Board's collection of testimony. If anything it would be even more eye opening.

Of course we still don't know what conclusions they came to, or how they summarized their findings. But on this note, we might infer some of it by actions or policy changes that were made. I am told by aircrew members who were there at the time, and current MAC crew members, that pilots now have charts that indicate where the Olympic Mountains are. Of course navigators are no longer a part of the normal overseas crews because 141s now have INS[138]. There also now exists a formal instrument approach over the Olympics which would give DME and radials and minimum descent altitudes at various points. But, I am told, this instrument approach like many others are coopted by radar vectors. McChord 141's still routinely come in over the Olympics under radar vectors. You've just got to know those mountains are there.

Other than that, nothing changed. Sixteen hour days are still routine and 24-hour augmented crew duty days are still part of policy. Flights still leave at all times of day or night. And since Desert Shield/Storm has been on, a crew of only two pilots with not even a navigator to back them up has a basic crew duty day of 20 hours. As of this date, March 31, 1991, with the enormous logistical time pressures of the war having long been dissipated, MAC is still running such 20-hour duty days even on state-side missions -- missions which are ferrying the troops back to home bases.

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138 Inertial Navigation System.

The Collateral Accident Investigation contains Col Pennella's nine page report to MAC headquarters. It is organized into five sections: I. Authority (one paragraph), II. Matters Investigated (a one paragraph description of the accident event), III. Facts, IV. Discussion, V. Summary of Evidence. The authorization orders for Col Pennella to conduct this investigation directed him to prepare a report "IAW AFM 120-3, Chapter 11 [procedural guide], [which] will include recommendations but a summary of the evidence will be prepared in lieu of findings." Either there were no recommendations or they were removed before the Collateral Accident Investigation material was sent to Senator Magnuson.

I have quoted from some of this management summary report already. Key indications that reflect on the Investigating Officer's interpretation of the evidence and testimony are the following excerpts or paragraphs in full.

Under discussion of the mainenance problems at Yokota, the following summary comments are made:

> Both navigators elected to take the aircraft as it was and changed the entry on the Form 781A from mission essential (ME) to maintenance convenience (MC). The weather en route to home station did not indicate the presence of any violent weather, so this would not be an unusual practice if the aircraft commander felt that the mission could safely be completed.

Under discussion of the aircrew's communications with Seattle Center, the comments relating to the incorrect descent clearance are the following.

> At 0556z, MAC 40641 reported level at 10. Seattle Center replied, "40641 maintain (hesitation) five thousand." MAC 40641 acknowledged, "Five thousand 40641 is out of 10." The controller, by his own testimony, was reviewing the minimum vectoring altitude chart in anticipation of descending V28323 to a lower altitude. This would account for the hesitation to his transmission. He believed he had given the clearance to 5000 to V28323. Normal traffic continued until 0559z, when V28323 called, "Seattle Center 28323 level ten thousand." Seattle answered, "28323 level at five?" V28323 said, Negative level 10 thousand." Then Seattle cleared him to five thousand. The controller still believed that he had given the first clearance of five thousand feet to V28323 and the aircraft had not acted on it.
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> Descent procedures for aircraft arriving at McChord AFB from the north do not follow a set pattern. Seattle Center controllers claim that they seldom give clearances to aircraft below 10,000 feet before handing off to McChord approach control.[139] If they ever do, normally upon request from the pilot or during icing or turbulent conditions, they must coordinate the descent with McChord AFB approach control because McChord AFB

139 My note: Actually, this comes from the statements of two higher level Seattle Center managers, not controllers. It is clear that if this could have been well established, more of the culpa would be on the Air Force crew for not catching an "unusual" clearance from Seattle, rather than not catching a clearance they actually expected to hear, but just came too early. It is understandable from the FAA's management perspective why they might have "filtered" a bit of the information toward this more favorable view from their perspective. The jist of their testimony was that it would be very rare for Seattle to give a clearance lower than 10,000 unless the pilot requested it. They may have been working from knowledge of the letter of agreement between FAA and McChord and not what actually gets done on a routine basis.

approach controls the air space below 9,000 feet. The pilot in the aircraft never knows of this coordination. A sampling of pilots from the 8th MAS, McChord AFB, indicated that descents are regularly given by Seattle Center below 10,000 feet before the handoff to McChord AFB approach. This difference indicates that there were no unusual circumstances about the clearance given to MAC 40641 that might have alerted the pilot or crew that they were receiving an erroneous clearance.

Summary comments about weather and navigation charts also painted things favorably from the Air Force perspective. No mention was made on the lack of Olympic Mountain terrain information on the charts pilots use.

The weather at McChord AFB, Washington, and vicinity during the period MAC 40641 would have made its descent, approach and landing was above minimums. However, cloud layers over the Olympic Mountains were estimated from 1,000 feet to 15,000 feet and visibility would have been less than one quarter mile in clouds and light snow. Little, if any, visual contact with surrounding terrain was possible during descent.

En route and terminal navigation charts and terminal approach procedure books (Let-Down Plates) which the crew signed for, and carried from McChord AFB were current. All flight documents were in order -- see MAC Form 103. The currency of these flight publications and navigational charts are not a factor in this accident.

Pertinent comments about the crew included an overall statement and a favorable summary of each crew member. Of interest here are:

The deceased crew members on this flight were considered to be well qualified and extremely conscientious in their crew duties. ...Flight evaluation records disclosed that the crew of MAC 40641 was qualified in accordance with applicable directives. ...No evidence was uncovered which reflects that any misconduct on the part of any member of the crew in any way contributed to the accident.

1Lt Evans' most recent flight evaluation ...was highly satisfactory and his performance was judged extremely good. A simulator evaluation ...reflects a completely satisfactory performance with excellent knowledge of systems and procedures.

Capt Eve's most recent evaluation ...reflects a very professional manner and an excellent knowledge of all applicable regulations, with a recommendation for continued duties as an aircraft commander. Although several testimonies indicate that Capt Eve was giving Lt Evans a buddy ride, this was not true. Lt Evans had received his buddy rides and this crew just so happened to have two qualified aircraft commanders aboard.

The comments about the other crew members were routine. A couple of specific comments about the navigators are worth quoting.

It is important to note on [1Lt Lee's] initial qualification flight that remarks contain a statement that his approach and departure monitoring was excellent. ...Lt Colonel Thornton's most recent flight evaluation was ...completed in an outstanding manner. Comments include the statement that he used all navigational aids to his best advantage and it was recommended that he be considered for upgrade to Instructor Navigator.

The discussion section included paragraphs on descent and approach procedures, citing regulations that require breifings prior to both phases of flight. These I quoted earlier.

The following comments about the crew are pertinent to our discussion here.

> Testimony substantiates that crew rest was taken in accordance with existing MAC directives.
>
> Although there was some testimony indicating that the crew was probably experiencing the normal amount of fatigue associated with a flight of that duration, there was no substantial evidence that either fatigue was a major contributor to the cause of the accident or the absence of fatigue could have prevented the accident.
>
> [The Senior Master Sergeant Standardization Loadmaster] deplaned at Yokota AB and went into crew rest to wait for another 8th MAS crew. This is normal procedure for flight examiners in the system to accomplish as many check rides as possible.
>
> Extensive inquiry of all witnesses and a review of all evidence indicates that management practices and supervision were in accordance with existing directives and practices.

And finally, in the summary of evidence regarding Seattle Center, Col Pennella describes the basic facts of the controller's mistake.

> A Seattle Center FAA controller for sector 3 mistakenly directed MAC 40641 to descend from 10,000 feet to 5,000 feet over the Olympic Mountains in an area where the average terrain was in excess of 7,500 feet. The aircraft descended into and struck the northwest face of Mount Constance on the Olympic peninsula, Washington. MAC 40641 was under positive radar contact at the time.
>
> Descent procedures for aircraft arriving at McChord AFB, from the north, do not follow a set pattern.

From what we have in analysis and summary from the two boards, there are only indications that point apodeictically to Seattle Center as the cause of this accident. Everything on the Air Force's part was "within existing Air Force directives and regulations." There is no mention of low experience, 24-hour crew rest issue, or the extreme level of fatigue that this crew was clearly experiencing -- none of the items that we have drawn out paradigmatically in this chapter. None of the "anything else you can think of" responses made the cut for the management report.

Why do you suppose these perspectives were filtered out? It was not because Col Pennella did not have the right witnesses or press the witnesses with tough questions or give them a chance to add, on their own initiative, what ever they felt might be important to the investigation. It was not because the witnesses were not candid and forthcoming. In large part, I thought Col Pennella's questions were pretty good. He picked up on points people made and pursued them with follow-up probes.

But we could see several places where his phrasing led some witnesses toward selective testimony; testimony that drew out favorable comments on the crews' judgment, especially Lt Evans' leadership and judgment. No one, from simulator instructor to crew members of various ranks and positions who had flown with Evans had any concern about his judgment. With Lt Evans' judgment established beyond much doubt as very solid, conclusions could be drawn about conditions that existed based on the decisions he in fact made. For example, additional testimony would be drawn out from a witness that mildly discounted earlier testimony that the same witness had given on fatigue. The pattern often involved questions after testimony on fatigue about whether the person felt that if Lt Evans had judged that fatigue would impact safe flight, would he proceed? Of course, the unanimous response was that he wouldn't. Other questioning pressed for apodeictic cause-effect conclusions which, of course, could not be made. Therefore, all the testimony about fatigue must not add up to more than the usual amount that all AC's must put their crews through to accomplish the mission; because that is certainly what Lt Evans chose to do. And we know he was a man of good conscious judgment.

After having pored over this material for countless scores of hours, I believe that Col Pennella attempted a very thorough investigation and that he did not feel, or was not aware, that he might be biasing the investigation. With knowledge of the blatant error of the FAA contoller, Col Pennella could have been predisposed to pursue any comments that might have pointed some culpability at the Air Force until they either dissipated, were discounted in some fashion, or rendered ancillary to the investigation. I believe that he discounted many of the things we have drawn out. He established with evidence on regulations and so forth what should have been done for proper flight. He drew out considerable testimony that indicated sound judgment, no history of reckless or unsafe decisions from this fully qualified crew; that every indication was that Lt Evans would do what he should do according to the directives. And he concluded that, because Lt Evans made the decision to go, none of these other factors must have been significant, whether it be fatigue, weather, radar, or what ever.

But that still doesn't explain it completely. What else is paradigmatically relevant in such official conclusions drawn from this accident? Think about the subtle filtering of information and the avoidance of disorder. We had a serious accident which caused considerable local disorder as we have seen. We have also seen several examples of the Air Force's effectiveness as an organizational complex, in adjusting to and limiting the spread of such disorder. In the Air Force investigations, information was, in general, subtly but selectively distorted to favor the decisions of the aircraft commander as proper and prudent, within normal practices. To not do this would mean the Air Force would eat more culpa than they needed to. They really could get away without eating any since the operator error on the FAA's part was so blatant. This minimized the disruption of this significant physical event to the MAC organizational complex.

But still, would the implications be so bad if, for example the Air Force could admit to perhaps even the potential of a judgment error on Lt Evans part because he was tired? What would be the nature and magnitude of the disorder caused to MAC if either investigation pointed out that lack of experience, or mission scheduling, or fatigue were serious issues in this accident? Well, they all would reflect on major flaws in high level decision making, policy and regulations, wouldn't they. The MAC commander, Gen Carlton, has responsibility for all of these things: the cost cutting moves of grounding the most experienced crews; the mission scheduling policy; the augmented crew policy; the crew rest policy; and all the things set out in regulations and directives which collectively represent the "bottom line." All these things that determine what the legal limits are that the "crews were within." And he has a great deal of impact on how much say flight crews have in such policy and the conditions under which they fly. He sets the tone for the culture by his actions and decisions, not what he says.

Col Pennella, who was the Investigating Officer for the Collateral Investigation, and virtually all of the Safety Investigation Board, including Maj Gen Saunders, the Board's President, were from some organization within Gen Carlton's Military Airlift Command. Gen Saunders was a direct subordinate of Carlton's and Col Pennella came out of the MAC headquarters staff at Scott AFB. The Safety Board did have two FAA representatives and one NTSB Safety investigator, which of course are outside of Gen Carlton's command. But they were non-voting members of the board. All voting members were from Maj Gen Gonges 22nd Air Force in MAC, of which you will recall the 62nd MAW at McChord is a part, or they were out of MAC headquarters. All of them are part of the same organization that makes the policies and regulations.

Are we to expect information that would cause serious disorder at high levels to come out of investigations whose boards have such structure? Think about it... To have either Col Pennella or General Saunders come back and report to their boss, Gen Carlton, with findings that said, "Hey General, we've dug into this accident deeply and we've found that your policies are all screwed up," is not a likely scenario! Especially when these policies have been in place for years and it just happens to be

General Carlton's watch. He's really not interested in causing disorders either. After all, these policies have tenure. They have survived many MAC commanders, and they worked just fine for them. It's not in Carlton's interest to seriously overhaul them.

It's just much easier to adjust to the disorder by blaming the operators. The first goof, to use remarks Gen Gonge made at the famous McChord base-wide meeting, was the controller giving the wrong clearance; the second goof was the crew accepting it. We have regulations against doing that -- end of case.

But, doesn't the system somehow allow crew feedback so that policies that put crews into treacherous situations like the 40641 crew, eventually get modified? Well, some perhaps, but it depends on the climate.

One positive example is the following. I mentioned before that it was unusual for airplanes to stay with the same crew all the way around the system. That is, when a crew went into crew rest, the plane was refueled and another crew came out of crew rest to take it on, thus keeping the planes moving throught the system. It's called crew staging and the main staging points in the Pacific MAC systems are Hickam, Wake, Clark and Yokota. But this staging presents two different scheduling challenges, one for managing crews -- how many are out in the system, where they are, timing of lay-overs, etc. And the other to schedule the airplanes and loads (loads is actually a third scheduling task); which means maintenance scheduling, load arrival, fueling, etc., etc. Now this is no easy logistics task. You can see why management has an invested interest in "no delays."

But, of course, it doesn't work perfectly. Sometimes a crew comes out of crew rest, that is, they are now available to be alerted, but there is no plane waiting for them. Maybe there was a scheduling foul-up, a load delay, a maintenance delay, or some young AC refused to succumb to the four-colonel departure. On top of that, it may be uncertain as to when the next plane is coming in. If ACP knows for sure nothing's coming in for the next 24 hours, say, they will give the crew a "release." That is the crew goes back into crew rest and can't be alerted again until the end of the release period. (By the way, crews are always calling ACP at some time or another during their crew rest to see if there might be a "release!" -- Yes!! Great! A release!!) This is especially true if you are coming within 10 hours of alert time and it's 6 o'clock in the evening and you want to know if you can have a beer or two with dinner, or how late you are going to want to stay up. You may get a 3 hour release (they don't usually give a release for that short of time, however) which extends your alert time by 3 hours making it legal for you to have your beer with dinner. If there was a remote chance of a plane coming in, though, ACP wouldn't give you the release.

But what do you do with the crew who is now either alerted or waiting to be alerted when there is no plane coming in, but there *might be* within their crew duty day? Or, you may get alerted, but in preflight you find mechanical problems that ground the airplane and prevent your departure. So you sit around on the flight-line and log "ramp time" until the plane is fixed. They might even put a part on the next plane out of Hickam, say, that will get to you at Wake 6 hours after their departure. And then the maintenance crew has to change it on the airplane.

The policy when I was flying with MAC, before I went to Viet Nam in 1971, was that the crew was "on the hook" the entire time. That is, say your crew rest period was up at 0800L, but nothing was in or you were alerted but had maintenance problems. You have a 16 hour duty day, so ACP could keep you in a "non-released" alert status for say 10 or 12 hours, giving you enough time to start a 6 hour flight at 6 or 8 pm that evening. Well, you're back in the situation where you're beat. You were on the hook all day, could be alerted at a moment's notice or you were sitting at base-ops, so you couldn't do anything or go anywhere; just hang out and wait. We always pissed and moaned about that situation which seemed to fall on deaf ears, year after year.

By the time I returned to McChord, however, in 1972, that policy had changed. So now, if nothing came in which had you alerted within a 12 hour window of your alert time, you went back into another 12 hours crew rest. And if you had already been alerted, they could only keep you for a 6 hour window. If the plane wasn't launched by then -- back to crew rest. Of course, then you had the "out of phase" problem. That is, you got up ready to fly at 0800L but went back into crew rest at 1400L, 6 hours later, and were now in a position to be alerted again in the middle of your sleep at 0200 hours. What a deal! But it was a step in the right direction.

That was the positive example of eventual policy change. On the negative side, a policy was instituted as a result of the August 28, 1973, C-141 accident in Torrejon, Spain. It crashed on a high plateau near the base killing 17 passengers and seven of the eight-man crew. This accident caused sufficient organizational disorder that it precipitated a change-in-policy response from the MAC Commander. It was referred to a the "integral crew system." The MAC Commander felt the crews were too lax and needed closer supervision. The system basically consists of a set of policies that tighten up on all aspects of crew management, from training and evaluation to scheduling. This was accomplished by identifying a set of crew members who would always fly with each other, instead of the normal situation where you had no idea who was going to be on your crew until you showed up. The integral crew system works okay for SAC because they do a lot of sitting around on alert or fly training missions. Whereas MAC has to have a great deal of flexibility in scheduling. This was extraordinarily difficult with the integral crew concept. Not only that, there would get to be conflict among crew members because you might get an AC who liked to fly a lot but other didn't, or vice-versa.

One of the squadron Standardization Majors brought out the impact that this upper management decision and its associated policies have had on crew morale and attitude, especially when the crews feel that their concerns never got heard by the brass. He felt that this impact on attitude could carry over into the way they did their flying job. Here is his story as presented in response to Col Pennella's questions.

> Q: Have you anything else that you can think of that would help us determine what happened in this accident?
>
> A: This is an opinion, and it will be treated as such I am sure, but the general morale and attitude of the aircrew members has changed. I observed it over the period of August of 67 to the current date. I endured some 5000 hours in a 141, other than the year I spent in Vietnam. Some of the management changes that have been imposed over the last two and a half or three years are at odds or contrary to the likes and dislikes of the crew members.
>
> Q: Could you give some specifics?
>
> A: The primary thing that we've been fighting -- well, maybe fighting is the wrong word, but have objected to -- is the integral crew system. This came about as an outgrowth of the Torrejon accident and was an attempt on our Commander's part at MAC level to impose a situation that would improve the supervision of our younger crew members. I am appreciative of the position that he was in, that he didn't have the old, sage, MAC crew member, that image that we operated with for so long, to fly his airplanes and that possibly the management change was needed. But the supervision that was desired at that command level, in my opinion, has not materialized, and in some cases we have had a reduction in discipline on the basis of imposing these integral crew policies. The management of scheduling, the management of training, and the management of standardizing an integral crew system, the proficiency requirements, the changing of reference dates, has added a tremendous workload to those who have to schedule, to those who have to evaluate, to those who have to manage.
>
> On many occasions I feel that feedback has been given back up the line, the command line, and I personally have been associated with enough higher headquarters people to know that they were aware of how the crew members felt toward the integral crew system, and how the first-level and the second-level managers also felt. We haven't had any response to this and it's pretty much directed that it would be done.

I feel that someplace our boss up the line either has not gotten the proper word or chose not to take the words that he got.

Q: How can you relate what you're telling me to the cause of this accident?

A: I would take it back, once again it's an opinion and a feeling that you get with a crew, and I am an evaluator and fly with a lot of crews and have flown over that long a period of time. This condition on a crew today is different than it was, let us say, in early 71 or 72. I have more concern today than I did then, personally, when I fly, even as an evaluator. I don't think you'd ever find me asleep on a descent, even though I had flown 31 hours, I have a respect for the fact that we do have inexperience and that we don't quite have the attitude that we had before. Maybe I'm not putting my finger on it, but there's a different feeling in the 141 crew members than we had when you were flying 141s -- you said you had flown them quite a bit yourself. It just feels different on the crew. Call it discipline if you want, that's a broad field of things.

Q: This was not an integral crew.

A: No sir, but the crews that fly don't know if they're integral or not and it doesn't make a bit of difference to them.

Q: This feeling that you are trying to describe which is very difficult evidently -- do you think this is a factor on people's proficiency or their attitude toward performing professionally?

A: I think it would be more of a reflection on the attitude that we are talking about, this feeling that I am trying to convey to you, it is an attitude, it isn't proficiency. We still have people that are capable of making landings, takeoffs, navigators that are capable of monitoring approaches and departures, they shoot three stars, this is my job to go out and see the "can" part of it -- Can the person do it and did he do it, in the evaluation. I don't have any qualms in saying that everybody on that crew well filled the "can" part, or they could do the job, and our evaluation records show that on a single incident or at a specific time they did do the job when we evaluated them.

Now we are faced with the problem of will they do it, and the fact that you and I are sitting here talking is pretty clear that they didn't, and that has to be supervision somewhere. They didn't do what they could do. That goes back to attitude. In my case, maybe I'm getting a little too behavioralistic. I have just finished getting a Masters Degree in Business from SIU and I probably am a little bit more sensitive to what makes people do the things that they do. But there is an attitude, and the attitude is not good.

Q: Do you have a solution to change this attitude?

A: The pet solution of the crew members would be to do away with the integral crew system, although it would probably have a little bit more mature look to it than that. I do realize what our Commander was trying to do was to generate a situation that would provide better supervision. I don't feel that we've done it with the integral crews. I still feel that maybe he had the right idea in how we would increase the supervision with our younger crew members. I don't have a replacement for it, although if you ask any of the younger people I am sure their answer would be, "Well, it's very simple, just get out all of the old regulations and let's do away with the integral crew system." I've been around too long to say that that would be a cure-all, although that is what people would like to see happen.

Of course, we wouldn't expect any of this to make it into the summary reports to top management on the accident. Which it didn't. I am told that the integral crew policy didn't last too long, but its demise had nothing to do with the 40641 accident or subsequent investigations. It was dropped sometime in the late 70s.

Summary and Lessons

So, we find ourselves faced with a much more complex flight safety situation than is readily apparent from an apodeictic explanation of this accident. The aircrews all know this, by the way. They know what *really* was behind this accident from their own experience on the line. They also know the disorder any policy improvements for the crews would cause on the MAC operation. Somebody would have to figure out how to do things (like scheduling) differently. Much more management effort would be required to "get the job done." Policies would have to be changed which would induce additional constraints on MAC operations flexibility. It would be perceived as adversely affecting the ability of the Military Airlift Command to accomplish its mission.

But accident investigations find it hard to point cause at things that are contextual. Apodeictic explanations are proximal and they seek cogency. They constitute a scientific approach to investigation. They want a definitive answer. They follow direct cause-effect or sequence-of-events reasoning based on an understanding of the physical scientific principles involved. It is felt the answers can be obtained this way, even if a bit too late.

The bolt which held the pump in position broke due to a fatigue-fracture failure which resulted in the pump coming loose and dropping into the control cables binding them up such that the increased force required to overcome the subsequent restriction to control surface movement could not be generated by the pilot in order to recover from the dive which caused the airplane to hit the ground with such force that it destroyed the airplane and killed all those aboard.

> All fatal airline accidents and many that are not fatal, get the full NTSB treatment, resulting in detailed reports of the circumstances that led to the accident, the sequence of events, and the assignment of principle and contributing causes. ...Careful study of the root causes will almost always show that the accident had been waiting to happen, that it had signaled this fact through smaller earlier breakdowns or in other ways, and that it was always preventable in retrospect. Retrospect is a great tool, but it is never there when you really need it, in advance.
>
> ...[However, it does] force the system to learn from experience. For each accident for which a root cause can be determined, recommendations are made for reducing the chance of recurrences. These recommendations may involve rule changes, modifications or inspections of aircraft, improved or modified training for pilots or non-flight personnel, changes in manuals, or just warnings to be careful about something.[140] [141]

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140 Like mountains and wrong clearances, I presume.

141 Lewis, H.L. (1990). *Technological Risk.* Norton & Company, New York. p197-8, 204, 209.

It was an operator error in that the controller gave a wrong clearance which directed the crew to descend over hazardous terrain flying them into the face of a mountain which resulted in such rapid deceleration (we could even quantify it) that the restraining force of the seat belts on the midsections of the occupants' bodies tore them in half causing severe trama which, coupled with the impact of now loose body parts with metal and rock as the plane structure collapsed, resulted in severe crushing of vital body components such as the skull causing death.

Now, we can follow the cause-effect chain in either direction (we don't usually need to go down as far as an autopsy to determine the cause of death under such violent circumstances). We can back up to the initial conditions of the bolt failure -- what material it was made of and so forth, until we find ambiguity that is unresolvable due to the ambiguous scattering of initial conditions. Like, was there a micro-structure flaw -- a slip plate in the molecular structure of the alloy, maybe, when the bolt was formed. Or, was it tightened too tight, and so forth. The situation can be subsumed under a multitude of laws depending on what the initial conditions were, which at some point are ambiguous. We can improve the design of the pump bracket, the bolt, relocate the pump, put backup systems in and so forth, and eventually feel comfortable that we have thought through all the possible ways that this type of failure could happen and thus be prevented. We can usually find technological fixes once the event has occurred.

We can back up to determine that the controller didn't have his radar PVD on horizontal when it was in broadband mode, as required by FAA procedures. We can ding him for that, but we don't know that he still wouldn't have made the same slip. We can determine that the pilots took the clearance without question; that either their equipment was such that they were unable to tell where they were (unlikely, since there was no indication of minimum nav aids; but of course the TACANs could have broken lock temporarily, as they do), or that they didn't follow procedures, which are spelled out in regulations for their own safety -- in fact things that "warn them to be careful" in order to prevent just what happened.

But beyond that we just can't say much in an apodeictic explanation sense. As soon as the causal lines run into multiple branches due to ambiguously scattered initial conditions, the complexity is impenetrable. You can't "prove" this or that "caused" the controller to make the slip. You can't "prove" this or that "caused" the pilot not to check the clearance out. Thus the apodeictic explanation stops conveniently at either a piece of equipment failure or an operator failure. Anything that is contextual, such as senior level management policies, organizational culture, and so forth, escapes critical examination and improvement.

Apodeictic explanations do not allow much penetration into the *context* of aviation safety. Because the method of explanation seeks cogency in its argument, it cannot penetrate the complexities of the context for a specific accident. Because science is the accepted standard of explanation we do not get past the accepted mind-lock that the apodeictic cause-and-effect approach to explaining accidents, and aviation safety in general, has on our cognitive framework. We only *see* aviation safety from that framework. And it's a community mind-lock as well. Who within the community will be so bold as to "conjecture" some "cause" that can't be proved with scientific reasoning. These things are easily rejected as "could have beens" or "maybes" or "possiblys" but we can't really say that that's what it was.

You can't *prove* that fatigue killed that crew. You can examine lots of initial conditions after the fact and see where a different decision here or there might have prevented the accident -- but that is only after the fact that the accident occurred.

So whenever someone who brings up a concern is pressed to *prove* or demonstrate with empirical evidence that such and such a condition -- lack of experience, fatigue, laziness, low morale, poor judgment, radar maintenance scheduling policy, controller staffing policy, what ever -- *caused* the accident, they must back off no matter how strong their gut feeling is. No matter how strong that emotion and intuition are, which are based on a vast amount of experience living with the impact and results of those kinds of things. As long as we hold science up as *the sole model* of explanation, so long as we hold objectivity to be *the virtue* upon which our knowledge and understanding is based, we must admit that the contextual factors that we have strong feelings about do not measure up under those standards of cogency. We are left with cogent proximal explanations that leave us unsatisfied because the context doesn't get penetrated, examined or changed.

If we take a paradigmatic approach, however, and do so in a manner that is not premature or facile, we can gain great insight and understanding of the contextual reality with which we are faced. I have examined one accident in great depth and explained it from a paradigmatic perspective. I did not, however, start this work with this accident and pick out things and extrapolate them to broad patterns. I first developed broad patterns, a set of paradigms that were explanatory of reality in general -- patterns which social, psychological, philosophical and engineering researchers and thinkers have pointed up as paradeictic explanations of reality. The MAC 40641 accident serves us not as "proof" but as a pedagogical case study. It is a paradigm of the contextual phenomena we have discussed.

We have drawn upon literally life-time works. Whether it be cognitive patterns and the notion of a framework. Whether it be patterns of accidents that recur over and over again in complex systems in such a way that we come to expect them as "normal" accidents. Whether it be the pattern of technology as it manifests itself in the functional procurement of devices to increase availability of commodities, with safety obsequious to all other aspects of availability. Whether it be the background expectations of a technological society that sustains the machinery of our technological world and sustains the differential pressures on the various aspects of availability. Or whether it be the patterned character of organizational complexes, complexes which may hold up formally stated goals as the basis of their behavior, yet nonetheless are better understood paradigmatically as adaptive systems in which information is systemically distorted in a favorable way due to their natural tendency to avoid disorder.

I have placed the examination of this accident in the context of these paradigms. Through the lengthy presentation of experiential knowledge as told deictically by the stories of those who live that life, interwoven with relevant apodeictic scientific understanding, we are now able to understand the context of 40641. The accident itself, as it is contextually engaged with organizational, technological, and cognitive reality is a paradigm of aviation safety.

So who are we to blame for the death of this crew, who *caused* this accident: the controller? the aircraft commander? the navigator? other crew members -- Capt Eve who was just sitting there in the jump seat do nothing but monitoring the situation? human frailness? Air Force maintenance? FAA maintenance? management policy (enforcement of regulations, maintenance, scheduling, staffing, MAC, FAA)? organizational culture? technology?

What was thought to be an apodeictically arguable question is in paradigmatic reality exceedingly complex. The question doesn't make sense. That whole approach doesn't make sense. What makes sense is explanation and understanding. And that means both apodeictic and paradeictic explanation, for the insights are complementary. *That* is what can help guide us to improvement of the climate for aviation safety and the prevention of accidents -- not *who is to blame*. The explanation contains enough for everyone to do some process improvement.

When we expand our minds the tables get turned for a change. Instead of operators struggling to argue that there is more to it than cut-and-dried cause-and-effect, *what if* long standing policies no longer had tenure? *What if* instead of an operator -- a pilot, a navigator, a controller -- having to prove that management policy results in chronic fatigue or equipment down time which results in mistakes which results in accidents, which results in loss of lives; what if management had to show that policy *does not* have those effects. *What if* our thinking about the burden of proof were turned around. In other words -- prove that it *doesn't* have those effects rather than prove that it does. What if no policy was allowed to stand without such proof.

This is a paradigmatic dilema of apodeictic arguments. The policy makers cannot apodeictically argue their way to a cogent conclusion either. The only directional imbalance is that of power. Policy makers have it and operators don't. And it is an enormous power in its ability to dampen out disorder.

This is why the operators are invariably left holding the bag. The *stage* upon which they perform is fraught with hazards that result from decisions and conditions far beyond their control. And if they stumble, the stage managers can always say -- "We told you not to trip on that." Or if the one item they tripped on is too obvious for the audience, they may pick it up and move it somewhere else. But the stage itself never gets cleaned up -- it only gets more cluttered with hazard because information about its condition comes to light only through the illusionary effect of selectively filtered stage lighting, screens and curtains.

It is high time to raise the curtain, turn the lights up bright and clean up the stage!

Conclusions:

The question of who is to blame is not only improper it is indecent. It is not everyone; it is not no one; it is not anyone; it is not someone. What we have learned is that MAC 40641 was a normal system accident that occurred in a sociotechnical system of very broad scale -- a system of interactive complexity with locally tight coupling, but contextually loose coupling. The interactions were unexpected and incomprehensible. No one could foresee all of the things that would come together and interact in that way. No one caught the local incongruities -- not the crew, not the controller. No one caught the contextual incongruities. No one would ever expect such circumstances to converge -- the down-time scheduled for the FAA computer, the combining of positions R3 and D3, the Navy plane who would be traveling north 65 miles away from the south bound MAC plane yet receive exactly the same 10,000 foot altitude clearance, the unfortunate timing of their respective arrivals at 10,000 feet and their subsequent reporting "level at ten," the 5000 clearance that both would expect and both would get. No one could foresee that aboard this MAC plane entering this familiar and routine flight environment would be a handicapped crew -- handicapped by fatigue beyond belief due to mission scheduling policy, handicapped by lack of experience due to staffing policy, handicapped by lack of an operating radar due to cultural pressures to "make the mission happen as scheduled." No one would think that a crew who had gotten up for the last time in their young lives 30 hours before, a crew that had only two 9-hour sleeps in over three and a half days, a crew whose biological clocks were grossly out of sync having had traversed 18 time zones -- no one would think that such a crew would end up not completing what was routinely expected from MAC crews. No one could foresee that an organizational culture would tempt a bright, responsible young pilot to unwittingly press the edge of prudent judgment with the cards stacked against him.

The stage was set. Could no one foresee that this cluttered stage just needed a tiny triggering event -- an event which arrived in an unlikely small time window? That for the sake of a few seconds -- a call "level at ten" just as the controller was examining a minimum altitude chart for another military radar target; for the sake of a tiny little delay in their blind execution of the wrong descent. Just a tiny little trip on a dark and cluttered stage -- one with stage equipment and props and scenery precariously scattered about and strung together in ways that a bit of a stumble would bring them all crashing down on the performer feeling his way about. A cluttered stage that was not properly lit in the airplane nor at the controller's station.

The McChord airplane with its exhausted -- but competent and qualified -- young crew coupled themselves tightly to that controller. Exhaustion short circuited the buffer that was "designed in" by regulation and training and reinforcement and professionalism -- all those things that reminded them they must watch out for the stage clutter, especially when the stage is dark. When that happened, when the buffer was eliminated, they were no more than an element in the servo-mechanism model that is used to model human-machine systems. They were knob turners for someone on the ground who was flying the airplane, making all the decisions -- the planes direction, its altitude, the timing of its descent. A robotic servomechanism in the air tightly couple to servocontroller R3-D3 on the ground.

The stage was set with all its clutter for the blind crew -- and then -- just a small human slip, the kind we've all experienced ourselves in everyday communication, triggered the event -- and lives were changed forever.

The stage came crashing down upon the performers. Yet all the clutter remains for all the performers who follow on the same old stage.

Post Script: Technology, Routine and Fatigue

This is an appropriate place, I believe, to ponder a few thoughts on the implications of advanced technology in the context of this accident. If fatigue is to be accepted with flying, at least international flying, and fatigue exacerbates the propensity for humans to make errors, then perhaps we should further disengage the human from the active loop of flying. I have noted earlier that the trend in automation technology is just that -- removal of humans from the machinery of the device.

There are, of course, many questions unanswered in this regard. However, it is well known that while increased automation may help in reducing pilot workload and improve flight efficiency, its converse effect is to increase crew boredom and encourage over-reliance on automated systems. The problems with humans as monitors are also well known and are explored by several contributors to Wiener and Nagel's *Human Factors in Aviation* [420]. Complacency is an issue that just doesn't go away with automation, in fact just the opposite. With computerization enabling so many ways for warning crews about malfunctions and procedural lapses, the tendency is toward a feeling that the airplane will tell you when something is wrong. Further disengagement is implicitly encouraged since vigilance and attention to procedural details appear less critical.

The more disengaged from the flying task, the further away the pilot is from the cognitive framework necessary to *assume control when unexpected situations present themselves,* whether it be traffic, weather, controller errors, or emergencies. That is the way we must frame this situation. The pilot serves as a backup to computer controlled systems that run the airplane in an optimally efficient manner. This will not change because the paradigmatic pressures of efficiency will dominate the scene. Policy setters and staff people who work for the organizations that own and operate the aircraft will subsume more and more of the decisions in the cockpit. Computers will keep a record of flight conditions and pilots will have to justify decisions that take the aircraft out of its optimal -- meaning computer driven -- mode of operation. They can only do less than 100% of the computer controlled optimum -- a theoretical optimum that is measurable. It could even become a relative performance measure among airline Captains. Ones who might like to do a fair amount of their own flying

-- just for the hell of it, because they like to fly -- will rate lower on their pilot efficiency index, even if they are better pilots because of it. The paradigmatic pressures are there which will tend to keep the airplane coupled to the computer.

One of the oldest cliches of flying is that it constitutes hours and hours of boredom punctuated by moments of sheer terror. It appears that as automation technology continues to functionally partition the task environment and subsume responsibility for more and more of the tasks, the crew's role becomes more that of data manager than "flying" per se. This calls forth a whole set of needs and functions in a paradigmatic way. Data entry verification, for example, then becomes a need and we know that humans are prone to make errors in data entry of any form. This calls forth the function of automated uploading and downloading of data. Computers can be programmed to check parametrically all data for its proper range, logical requirements and so forth. The obvious parts of data management will be taken care of in an increasingly automated fashion. [421] What will be left are the unthought of subtle incongruities which will be ever more hidden and removed from the foreground.

We have discussed the patterned functional isolation of needs in the paradigm of technology. Technological fixes for such issues mentioned above may address ever more isolated needs but in the process needs become unlimited and more removed from context. The human operator becomes more isolated and disengaged. Graeber writes:

> The critical issue is the change that automation is bringing about in the crew's job requirements. Many of the stimulating and rewarding aspects of flying may be eroded as less and less manual flying is called for, or even permitted, by individual carriers. By reducing workload and providing precision information processing, on-board computers have eliminated many sources of crew error, but they have simultaneously increased the subtlety of error detection. The increased use of radio transmitted datalinks and stored navigational data bases may help to decrease the dependency on crew keyboard entries and thus the opportunity for input errors. Therefore, crews then become even less familiar with the input procedures necessary when en route flight plans must be altered unexpectedly. [422]

Now what was paradigmatic about 40641 was not that a relatively low-tech airplane, by today's standards, accepted a wrong clearance and flew into a mountain. In other words, one might categorize this by "accident type" and proceed to examine it apodeictically for all the possible reasons airplanes fly into mountains under radar control and what technological fixes could prevent them from doing so. [423] What is paradigmatic about it is things like cognitive framework and recognition of subtle incongruities under extremely routine, familiar and apparently safe environmental conditions. All in an emotional context of stress induced by fatigue and exhaustion.

All of the problems mentioned above are magnified from fatigue and sleep loss. Graeber's knowledge of the research in the field brings us a categorization of the effects of fatigue and sleep loss on flight crew performance. He pulls it together loosely under four performance areas of impact, among which we would expect considerable overlap and interaction. They are psychomotor skills, sensory-perceptual awareness, cognitive ability, and affective state. He finds in general that under conditions of fatigue and sleep loss, reaction time is increased. There are more timing errors in response sequences, control is less smooth and enhanced stimuli are required.

Attention is reduced. Sequential task elements tend to get overlooked or misplaced. There is preoccupation with single tasks or elements as multitasking ability is reduced. The performance of audiovisual scan is reduced -- in general there is less awareness of what is going on. In particular, there is less awareness of one's own poor performance and of that of other crew members.

Memory is diminished. There is inaccurate recall of operational events. Peripheral tasks are forgotten and "old" habits are reverted to.

The affective state or mood becomes more withdrawn. Individuals are less likely to converse just when, in fatigued condition, it is even more important to converse. There is a tendency not to even perform low-demand tasks. People become more irritable and distracted by discomfort and there is more of a "don't care" attitude.

This is precisely the kind of situation that happened with the 40641 crew under the control of radar vectors and altitude directives from contoller R3-D3. Precisely this situation becomes paradigmatic. You see, it doesn't need to be R3-D3 generating a subtle incongruity in the context of familiarity, routine, fatigue and so forth. It can be little R2-D2 in the instrument panel doing the same thing for you.

> The computerized cockpit may *exceed* the capacity of the conventional cockpit to trap the tired crew member into performing incorrectly or not at all. When you are tired, there is always the temptation to conserve energy and let someone, or something, else do the job. It is reasonable to expect that the resident expertise and compelling displays of highly automated flight-deck systems will heighten this tendency, especially because ordinary in-flight procedures will require less crew member involvement. Added to this performance threat is the impact of automation on crew complement. [424]

Graeber goes on stating that we have little knowledge or experience with two-person crews on long-haul flight operations. All next-generation aircraft have "designed out" extra crew members -- the two pilot crew is the basic crew. Currently airlines carry a third "relief" pilot for extended operations on two-man aircraft; but, where might we expect that to go paradigmatically unless pilot unions continue to cause more disorder over the issue than that caused by the paradigmatic pressures of availability and economic efficiency? The call will be for more technology to functionally address the *need* to continue with the third relief pilot. Air Force pilots have no union, of course (not that they should have), and MAC pilots are routinely flying 16-18 hour days -- and, more recently, 20-hour days -- with only two pilots on board. Also, increased automation has extended aircraft ranges and some can now fly beyond 14 hours. This means not only increased boredom but more time zones crossed with resultant affects on mood and all the other behavioral and cognitive factors we have discussed.

There are no easy solutions to these problems. But one thing seems obvious. As technology has the pattern of increasing availability of the final commodity -- air travel -- we need to think more seriously about the availability of that commodity that is in such short supply for crews -- sleep. Graeber mentions that such technological suggestions as in-flight procedures that will keep the crew more involved and interacting with the computers on board to overcome boredom associated with long flight, has the counter productive effect of masking the crew's physiological sleepiness in a soporific environment. The biggest help may be the lowest tech solution of all -- enlightened crew/mission scheduling policy, a sufficiently sized relief crew, and a truly well designed sleep environment on board for crew member relief -- and I mean *sleep* -- not "rest."

> The availability of demonstratably effective crew bunks for extra crew members may be particularly desirable on proposed long-range routes, instead of requiring crew rest to be taken in a passenger seat. ...The challenge of the new technology is to find ways of capitalizing on its strengths, so that crews can function more safely and not to be fooled into believing that its sophistication will compensate for the reality of our daily need for sleep and rest. [425]

Now that Dr. Graeber is head of Human Factors Research for Boeing it will be interesting to see if this human factors expert can generate enough disorder to influence future airplane designs in a way that will address these needs.

Chapter 10

Reflections

I will break these reflective comments into four sections. In the first I want to reflect on the broader significance of the 40641 accident. Secondly, I will put forth some general but tentative considerations for the contextual aspects of aviation safety. These should not be taken as definitive conclusions but more humbly as broad reflections on an extraordinarily complex issue which is just now seeing light in the research community. These can be taken as suggestive "meta-guidelines" for guidelines, if you will, with the hope of generating more discourse on this topic from all walks of the aviation community.

Then I will contemplate some thoughts on paradigmatic extensions of the investigation of aviation safety in general and accident investigation in particular. Again, the hope here is to further the pursuit of enlightened discourse among the professionals in this community. I do not purport to be a professional safety expert nor accident investigator. These traditional fields are not my areas of experience nor expertise. But I do believe they represent an area that is highly interdisciplinary and one which needs to open its windows to broader perspectives. It needs to be emancipated from technological guardianship which continues to entrap it in an apodeictic framework. If my work generates some disorder in the safety investigation community that results in new and better thoughts and ideas to come forth in the future, I will feel satisfied that this work has been a contribution.

Finally, I will make some specific policy recommendations for the Military Airlift Command and the United States Air Force.

Meta-lessons from MAC 40641

Perhaps the most significant meta-lesson to be gained from the MAC 40641 accident is the avoidance of two pitfalls which purely apodeictic analyses almost guarantee: blaming the individual operator(s) and perceiving the situation as unique, requiring only local fixes. These are the two recurrent human failings which James

Reason described as virtually universal institutional reactions to catastrophies (see Chapter 7). The technical terms for these were the 'fundamental attribution error' and the 'fundamental surprize error.' As we saw from the organizational paradigm, these two reactions are to be expected because coming to these conclusions results in the least *immediate* disorder for the organization. The organizational adjustments required to adapt to the physically caused disorder (the accident itself) are minimized in the short run. If the operators or a simple equipment failure were not perceived as the "cause" of the accident, or if the accident situation was due to a profound systemic organizational problem instead of a unique and rare set of situational circumstances, the potential disorder for the organization could be enormous. Ironically, though, the failure to deal directly with the broader implications and disorder virtually invites recurrent safety failures in the long run.

These conclusions are typical of the paradigmatic distortion of information -- especially that information which relates to safety. They are also paradigmatic in their representation of the cognitive framework which dominates safety investigations. Apodeictic explanations are insufficient. By themselves they simple miss the point. Reason's quote is worth restating.

> Although the errors and violations of those at the immediate human-system interface often feature large in the post-accident investigations, it is evident that these 'front-line' operators are rarely the principal instigators of system breakdown. Their part is often to provide just those local triggering conditions necessary to manifest systemic weaknesses created by fallible decisions made earlier in the organizational and managerial spheres. [quoted in Chapter 7]

It is interesting that the MAC crew members I have discussed this accident with expect the kind of conclusions that in fact came out of the investigation of 40641, resulting in no improvements of any significance. They are cynical about it. They *know* from their own experience with flying in MAC that there was much more to that accident, but they also *know* from their experience in the organization not to expect the core issues to be addressed. They have a sort of tacit understanding of the paradigms of technology and organizations. They "know" that the drive to increase the dominant elements of availability (ubiquitous, instantaneous and easily procured cargo transport) dominates safety; they "know" that to come to any deeply systemic conclusion would cause enormous disruption in the organization. This is the framework of those who operate in that world.

Meta-guidelines for the Context of Aviation Safety

Unfortunately, there is no set of "cookbook" measures one can just follow to deal with the contextual complexities of aviation safety. If in the aviation safety community, however, we hope to avoid these natural and expected fundamental errors, we must learn to view the world from a broader framework. We must expect these shortcomings -- not accept them, but expect them. Only then can we begin to deal with them.

Awareness

As I have emphasized throughout, the purpose of this effort has been to expand our framework for aviation safety. Recognition and understanding of the four paradigms which point up the paradigmatic context of aviation safety would go a long way in raising our awareness level. I do not expect easy acceptance of these ideas -- from aviation policy makers in particular. Why? Because I understand the implications of the paradigms and this new framework. It means a fundamental reexamination of how aviation safety is managed. The potential disorder would lead me expect the framework to be more or less scoffed at.

So let this be a guideline that is a little less ambitious. *Contemplation* of the paradigmatic nature of aviation safety can help *expand* our thinking about it. Drawing from the literature of a wide diversity of fields, as I have done -- fields well outside traditional aviation circles -- has provided many new concepts, terms and relations that can jog our minds into new ways of thinking. This is what I refer to as the "mind expanding" role of the new framework.

Now, it is not just in our individual minds that such a framework exists. Recall that a framework is something that is shared by a "community" as well. There is a "sociology of knowledge" whose core is the framework -- that internally supplied context we all assume is shared by others because we have learned it over long periods of socialization by communicating with others. What we need to do now is more "metacommunication." *Metacommunication* is a complex concept that is not without considerable historical confusion. [426] Wilmot is particularly interested in drawing out and understanding various types of metacommunication, such as relationship level communication. But my use here is his more generic portrayal of the concept.

> Human beings have the ability to communicate, and to comment on that communication. The message is on one level and the metamessage is on a higher and more encompassing level. ...Generically, metacommunication is anything that "contextualizes" or "frames" messages to assist the participants in understanding the communication event. [427]

Many of these "contextualizers" are built up by a repeated pattern of communication over time. Once formed they exert an interpretive function on all subsequent communications about a topic. So, what I am suggesting here is that we, as a community of people interested in aviation safety, must talk more about *how* we talk about flight safety instead of just talking about flight safety itself. We must *explicitly* recognize the existence of a framework that influences what we think about flight safety. We need to communicate more about our communication. We need to discuss the framework from which we view flight safety -- not just discuss flight safety. This will help expand our awareness and open up our minds to new ways of thinking which hopefully are more encompassing.

Also as a part of awareness I would include the need for increased discourse on a broader scale and enhanced public awareness. There have been some good works which have had this objective as their focus. [428] The counter to technological guardianship is the generation of constructive disorder. This is supposed to be the role of regulatory agencies, however, we have discussed the difficulty even they have of escaping the paradigmatic nature of the organizational complex they belong to. Doing this requires individuals who work in organizations (most all of us) to step outside of their functionary organizational role and get involved and speak up. This "speaking up" can be done individually or through one's professional organizations. A broader level of credible discourse must be sustained. This will not happen by functional organizational behavior, in which human perceptions are systemically shaped by the system we are involved with. It will only happen if we take responsibility for our own perceptions and this David Bella refers to as the practice of civil virtue. [429] In particular, he refers to the notion of civility.

> I define civility as those practices that serve to overcome barriers, disincentives, and differences in order to promote open, honest, and nonmanipulative discourse on matters of justice and the general good. Civility demands sensitivity, persistence, and sacrifice to encourage, nurture, and even force dialogue that is resisted by narrowness and self-interest, including one's own. ...If we take the democratic ideal seriously, then our concern for civic virtue must not be limited to the few (e.g., elected representatives, high officials). Rather, we would expect civic virtue, and thus civility, to be broadly practiced among the citizenry at large. Thus, in a democracy, one would expect to find pervasive networks of civility. The persons sustaining such networks would far exceed any list of high officials, experts, and elected representatives. Where barriers limit civility or civility is not broadly practiced, one does not have a democracy. [430]

In summary, awareness means open, credible and sustained discourse not only about aviation safety but about the framework from which we view aviation safety.

Contextual Engagement

The second meta-guideline I wish to put forth is the notion of "contextual engagement." This is a broad notion and it has applicability across the board from operators to designers to safety investigators to policy makers.

Operator Level

This is an appropriate place to pass on to you the essence of an excellent talk given by a well respected consultant to high risk groups (such as police and aviators), Chas Harral, entitled "Cockpit Mental Conditioning." [431] He relates four different conditions you can be in mentally while performing a high risk function like flying or controlling aircraft. These he structures around a color framework: condition white, condition yellow, condition orange, and condition red.

The tendency is to drift into **condition white**. Under this condition the tension level is off, you're sort of on automatic default. The situation is routine -- something like everyday experiences, relaxed, there is a loss of a sense of responsibility for anything. Humans have a tendency to get lulled into this condition. Under condition white you are disengaged from the context of your work.

So, unless you totally control your circumstances -- which you certainly cannot in activities related to flying -- you cannot afford to feel the comfortableness of condition white. This is the condition under which "mystery" accidents occur. Condition white will kill you.

Condition yellow is where you want to be. It is a state of relaxed awareness and alertness. You are looking, hearing, searching for the anomalies. It is not paranoia, but realism; being in charge of your circumstances. It is thinking in advance. If you're in condition yellow and you see what's going on you'll be astonished by the fact that so many people are in condition white. Harral says to observe a cat. It's hard to surprize a cat. The cat is not concerned with irrelevancies but with its physical security. Using another metaphor, he says "a commander can be forgiven for defeat, but never for being surprized."

Condition yellow is engagement with one's context. You have to work at it until it becomes part of the way you go about your business in performing your high risk activities. As the tension level or interference level within the individual increase, one's performance level increases. The transition then from condition yellow to condition orange is facilitated through your contextual engagement.

Condition orange is when a threat has been received. A warning signal of some sort has been perceived and the job is now to check it out. Being engaged with one's context is what helps one perform properly under condition orange thus preventing a tragedy.

Condition red is the ultimate default, but forewarned is forearmed. If your cognitive framework is prepared for this kind of condition you can be in charge of your default reactions. This is the strange condition in which you, at least for the instant, perceive you are close to death. Adrenaline flows, your pain threshold increases, your muscles tighten, your brain is "turbo-charged" and a fight or flight mechanism wants to take over. Harral related it to the audience by having the people think of a condition white situation in their backyards. You see a yellow wasp and then it lands on you. You go through yellow to orange to red virtually instantaneously. Adrenaline flows at 200 feet per second, he says, and the tingling you feel almost immediately is actually when the adrenaline is going away.

Certain physiological reactions under condition red can cause you to make inappropriate reactions, particularly if you are coming from condition white. They include magnification of vision, audio blocking and inappropriate audio discrimination (like hearing "unusual" engine noises that have always been there), increased physical strength, and time distortion by as much as 5 to 1. When we're in a stressed state it appears as if real time slows down and your body speed increases. You think you're reacting faster than you actually are.

There is one reaction under extreme stress, however, that helps you stay in charge. Harral calls it the ultimate default of survival and its ability to overcome the other default reactions and save you from a condition red emergency is related to how engaged you are with the situation to begin with. It is called the dissociation reaction where some part of you steps outside of your default robotic self that is handling the situation. Coming from a pre-red condition of engagement it can help you find a solution while condition red things are happening to you.

Before leaving the operator level, another example of a mechanism to help with contextual engagement comes from a recent emloyee initiated activity among Seattle ARTCC controllers in the FAA. It is called "CART" for Contoller Awareness and Resource Training. It started when a few controllers just wanted to get together and discuss how they could be more aware of what was going on in their work environment. It sort of took off by itself and got more organized and while employees were involved in this activity, operational error rates went down considerably. Management at first gave a tacit but skeptical approval of such an ad hoc employee initiated activity. Then they decided that there weren't the funds to continue it and it stopped. An experienced controller told me that when that happened the operational error rate went up again. Eventually it was reinstituted and now has developed such an outstanding reputation that controllers from all over the country are going through CART sessions.

What is so fascinating about this effort is that it came out of the desire of those employees directly involved with the controller activity to become more engaged with the context of their work. They discussed how to keep more engaged and be cognizant of things that are easy to overlook. In fact, CART was a process of engagement itself. Any organization could reap a lesson from this -- it's called empowering your employees. Those most directly involved with the context of their work are in the best position to understand the significance of that.

These kinds of things are also occurring in the airlines. United Airlines, for example, covers various things related to contextual engagement in their cockpit leadership and resource management training. Things they have identified as *key* for 1991 include an awareness list called "Red Flags of Awareness." It focuses on ambiguity, fixation/preoccupation, confusion, erroneous assumption, unresolved discrepancy, communication breakdown, failure to meet targets, departure from SOP's, undocumented procedures, no one flying the aircraft, lack of terrain awareness, and lack of traffic vigilance.

Designers

A new maturity toward technology should encompass an understanding of functionalism that we discussed in Chapter 6. The concept of *engagement* in the broader context should serve as a meta-guide for more specific design guidelines -- a sort of counterbalance to functionalism, if you will. The paradigmatic nature of the device has brought us enormous technological power to act on transformative possibilities ushered forth by scientific understanding. What seems to go unnoticed, however, is the subtle but pervasive disengagement from contextual reality that is brought on by the ever increasing purity of function and refined proliferation of needs.

As with most of these thoughts, they should be considered at more than one level. That is, design of aviation systems should reflect the need of the operators to be engaged in the context of their activities. But on a higher level the design process, itself, should also be more engaged with the context of aviation safety. Works such as that of Thomas Sheridan [432] are pointing in this direction.

Another contextual consideration is designing systems for resilience and sustainability; that is, focusing more effort on "safe fail" designs instead of having all of our thinking dominated by "fail safe." Perhaps we can gather insights from the natural systems that make up our world today because they are the ones that have survived the unexpected traumas over time. [433] Sure, we want to make every effort to prevent failures. But normal accidents won't go away. We cannot predict them in an apodeictic way nor can we design our way out of them entirely with technological fixes because of their very paradigmatic nature. It is not practically possible to foresee and prevent all possible interactions of multiple mode failures. They represent an unknown which must be coped with. Holling writes:

> The domain of our ignorance is vastly greater than the domain of our knowledge, and if we implicitly or explicitly plan on the presumption of sufficient knowledge, we can be certain that failures [of coping] will occur. [434]

Paradigmatic insight helps us understand this broader context in a more general way. It should become clear, for example, that we need to think more in terms of surviving those normal accidents that do occur. Recall in (Chapter 5), for a specific example, the lack of emphasis that Perrow pointed out in crash survivability of the cabins of airliners. We know that that is to be expected paradigmatically. Understanding that and continuing to raise the issue may eventually induce some effort toward the desired improvements.

Safety Investigators

The scope of safety investigation needs to be expanded broadly into contextual issues. Whether they are precipitated by an accident (or series of accidents) or whether they are initiated independently, safety investigations themselves need to become more engaged with the context surrounding the phenomena of aviation safety.

But has this not been accomplished to date? Recent joint industry and government initiatives to enhance aviation safety through human factors improvements were identified in Chapter 1. These are extremely positive developments for the focus of aviation research resources. The main theme is a growing concern about civil aviation safety as affected by human performance and it is supported by statistics which show that a majority of "the civil transport aircraft accidents were directly attributed to flight crew error as a factor to the probable cause." [435] This has lead to a human factors priority work program for industry and government which has identified nine separate program items needing more attention to improve the human factors influence on aviation safety. The overall goal is "to enhance aviation safety by developing and implementing human factors technology capable of reducing by 50 percent the rate of incidents and accidents caused by human error, and to provide a basis for preventing such events in the future. The implementation of this technology should also result in a positive effect on flight operating efficiency." [436] The focus of each of the nine programs is, respectively, to:

1. Determine principles of human-centered automation that will enhance aviation safety and improve system performance.

2. Provide an improved aviation system monitoring capability by expansion and efficient utilization of ASRS.

3. Provide an information base to improve the understanding of human performance factors, both positive and negative, in accidents and incidents.

4. Provide new and/or enhanced methods and techniques to measure, assess, and improve human capability in the aviation system.

5. Determine flight crew/controller needs and methods for information transfer in the flight deck, on the ground, and between the two.

6. Determine how new flight deck and controller workstation technology can optimally be applied and integrated to enhance safety.

7. Assess training needs and develop improved techniques for selection, training and evaluation of pilots and controllers.

8. Develop standards, methods, and procedures for certification and validation of human engineering in design.

9. Determine human factors affecting maintainer and inspector effectiveness and provide methods to enhance civil aviation safety through improved processes and practices for aircraft and ATC system maintenance and inspection.

A more specific initiative is the FAA's analysis of cockpit human factors research requirements. [437] This program addresses seven areas of contemporary concern in cockpit technology that have a direct bearing on flight crew performance:

1. Aircraft automation: Includes issues related to the influence of flight deck automation on flight crew capability.

2. Causal factors in accidents and incidents: Includes the development and maintenance of a program dedicated to classifying pilot errors and identifying the causes of these errors.

3. Human performance assessment and improvement: Includes issues related to aircrew workload and the effects of fatigue on crew performance.

4. Information transfer and management: Includes the identification of the information required by flight crews and the development of guidelines for the transfer and management of that information.

5. Control and display technology: Includes issues concerned with information transfer, and the design and evaluation of flight deck displays and controls.

6. Flight crew certification and training: Includes increasing the effectiveness of flight crew training and determining the minimum level of simulator fidelity required to achieve training objectives.

7. Flight deck certification criteria: Includes the development of systematic and quantifiable procedures for certifying advanced technology cockpits.

The overall goal of the nine supporting program elements of the national plan and the seven areas of emphasis in the FAA research needs document focus much needed technological efforts on reducing operator error. Unfortunately, there is nothing in these programs that focuses effort on contextual issues of aviation safety -- that is, a macro human factors perspective is lacking.

Most recently the FAA has begun a program to develop improved indicators of aviation safety. [438] This is a terrific idea. Its goal is to develop a consistent set of indicators which reflect the current state of safety in the aviation system and that suggest potential future problems or emerging issues. The methodology consists of a process improvement approach and is based on the premise that the level of safety is a function of the quality of performance of safety-related activities. This gets away from the quagmire of basing safety indicators on measurable changes in risk which suffer from some of the problems that were brought out in Chapter 1: the rarity of aviation accidents, the type of data available, the redundancies in safety standards, adjustments to the system and so forth. The whole orientation of the program has the flavor of a "Total Quality Management" philosophy that is currently pervading

American industry. In my opinion, it has the potential to effect very positive results in safety levels through clearer understanding and continual monitoring and improvement of the processes related to safety activities.

The focus of the program is on safety activities, the environment in which they take place, and the resources applied to perform them; these are considered for each major subsystem of aviation (air traffic, flight operations, aircraft certification, airports, and security). Examining the safety activity environment is intended to deal with the context in which activities are performed. The framework is an analytical categorization of aviation systems which seems fairly comprehensive.

Thus, it begs the question that points back to the null hypothesis stated in Chapter 1. Won't such a comprehensive effort that is intended, under an "aviation system framework," to consider the complexities and interactions of all the safety activity components be able to ferret out the contextual patterns I have shown to be worthy of consideration? As valuable and efficacious as the safety indicators (SI) program appears to be, it does not go far enough, nor can it without complementing it with paradigmatic insight. The SI program follows a classic apodeictic systems approach that necessarily has as its initial purpose a reductionistic separation and categorization of the aviation system into components conducive to the development of meaningful indicators for specific aviation safety activities. These reduced elements are then to be mapped against the FAA organizational structure and functions, the environment in which the activity occurs, and the resources used in the activity.

The focus on activities in an input-output framework, along with consideration of other activities that make up the environment for a given activity under consideration, goes a long way to document and understand the various processes. For example:

> Air Route Traffic Control Centers and Airport Traffic Control Towers are parts of the activity environment of the Air Traffic Subsystem, while Air Carriers and Air Agencies are part of the Flight Operations activity environment. Safety activities, such as the separation of aircraft or their operation, are performed within these environments. The performance of safety activities within the system determines the level of safety in the subsystem. The results of these safety activities are the outputs of the subsystem. [439]

This focus provides an "activity" context but it still does not penetrate very deeply the things that have been described in this work as paradigmatic. One immediate example jumps out from the "ideal" safety indicators criteria. The first criteria states that safety indicators should "be related to the risk of accident occurrence." [440]

That's fine; we would hope that there are continual efforts to reduce the occurrence of accidents. But we understand paradigmatically that "normal" accidents will continue to occur, however infrequently. What about coping with them? Is this not part of aviation safety? None of the eight criteria for ideal safety indicators address this. That is, the focus of the safety indicators appears to be on the prevention of the accident event (risk) and all of the various safety activities that might be related to the cause of the event. None deal with the hazard side of the issue -- the outcomes of the event, exposure to the outcomes, consequences of the exposure and the value of the consequences. [441]

Nor does the approach penetrate the paradigmatic nature of technology. The SI process control program itself is a device that will lead to improvements within the pattern of the aviation system device through a better understanding, monitoring and control of its machinery and functions. But it would not ferret out the very paradigmatic nature of the device itself and the implications discussed earlier.

Most of the data required in the development of safety indicators will be provided by FAA organizational entities. Because of the sensitive nature of some of the information, FAA administrators will necessarily control access to data and distribution of the reports. There is nothing in the program which would ferret out unintentional yet systemic distortion of information.

The safety indicators program, let me emphasize, is an extremely positive initiative, granting the paradigmatic caveats I have mentioned. But, in and of itself, it is not sufficient and I believe the program could benefit from some research and understanding in this area.

Policy Makers

In one sense policy makers are very far removed from the safety environment; in another sense they are an integral, if misunderstood, aspect of the safety context.

> A point has been reached in the development of technology where the greatest dangers stem not so much from the breakdown of a major component or from isolated operator errors, as from the insidious accumulation of delayed-action human failures occurring primarily within the organizational and managerial sectors. These residual problems do not belong exclusively to either the machine or the human domains. They emerge from a complex and as yet little understood interaction between the technical and social aspects of the system. Such problems can no longer be solved by the application of still more 'engineering fixes' nor are they amenable to the conventional remedies of human factors

> specialists. ...Those at the human-machine interface [are] the inheritors of system defects created by poor design, conflicting goals, defective organization and bad management decisions. [442]

Disengagement of top level policy makers, among many other players, is an enormous problem to address. What I am suggesting here is not more engagement in the details of aviation activities, but more concious understanding and engagement in the contextual processes that tend to "set up" the ultimate operating people for failure. The operators' part is so often simply that of creating the local conditions under which latent contextual failures reveal themselves. These latent failures Reason describes as...

> ...decisions or actions, the damaging consequences of which may lie dormant for a long time, only becoming evident when they combine with local triggering factors (that is, active failures[142], technical faults, atypical system conditions, etc.) to breach the system's defences. Their defining feature is that they were present within the system well before the onset of a recognizable accident sequence. They are most likely to be spawned by those whose activities are removed in both time and space from the direct human-machine interface: designers, high-level decision makers, regulators, managers and maintenance staff. [443]

Reason observes that much of the current work in the safety arena is geared toward active failures and has been focused on the operator and improving the immediate human-system interface. But as important as this work is, it only addresses a relative small part of the total safety problem. Attempts to discover and remedy latent failures will achieve greater safety benefits than will localized efforts to minimize active failures. This points up the need for a broad contextual understanding at all levels of the organization along with active engagement of top level managers in creating a culture which encourages the discovery and elimination of these latent failures. Reason proposes a very insightful approach to understanding the dynamics of latent failures.

Of course, we must again keep in mind that top level managers are under the paradigmatic pressures of the dominant aspects of availability and they work with such systemically filtered and favorably biased information. So there is not a lot that we should expect from them in terms of properly perceiving and acting on specific problems. What we can hope for, however, is an enhanced understanding of these contextual issues and a subsequent emphasis on them through appropriate allocation of resources and organizational priorities. Contextual engagement of management implies going beyond the futility of 'tokenism' which Reason describes as, "the con-

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142 Those errors and violations that have an immediate adverse effect.

centration of remedial efforts upon preventing the recurrence of specific unsafe acts." Enough disorder must be created for policy makers to see beyond the pitfalls of the fundamental surprize error.

Paradigmatic Extensions for Accident Investigation

A paradigmatic approach to accident investigation is an excellent topic for future research. What has been developed here has been a paradigmatic framework of the context upon which it might be built. Its essence would, perhaps, include an identification of and understanding of the concepts inherent in paradigmatic explanation, i.e., the notion that we can gain insight and understanding of extremely complex phenomena by reflecting the patterned nature of its context through the use of paradigms. It might also identify specific patterns which should guide investigators on what to look for beyond apodeictic causal mechanisms. That is, the current approach of explaining an accident solely through its causal mechanism could be complemented and extended beyond the ambiguous scattering of initial conditions which limit it pretty much to the operator and equipment domain. Through a better understanding of the pattern of technology, the patterned behavior of organizational complexes, and so forth[143], accident investigators would have a broader framework from which to pursue a more comprehensive explanation of the accident, penetrate the context of the accident and ferret out the "fundamental surprize" content of the accident. Such an approach could also present tools for looking -- things like interviewing, participant observation, and so forth. Maybe it should help the investigator convey an understanding of the patterns by appropriately pointing out their paradigmatic significance, tieing observations to well accepted and understood paradigms and so forth; perhaps even an effective use of metaphor to communicate an enhanced understanding of the context.

But again I feel an uneasiness about attempting to procure in a technological fashion the kinds of insights I have covered in this work. I am not at all sure it can be boiled down to a functional 'tool' with forms and techniques which will enhance its availability to each and every investigator. The paradigmatic temptation is surely there to develop yet another knowledge device -- a 'machinery' that serves the function

143 For a review of these see Chapter 3.

of procuring paradigmatic understanding of accidents ever more easily and effortlessly. I fear that the richness that comes merely from the awareness and insight that is gained from an enhanced cognitive framework on aviation safety will be lost as efforts are made to purify the functional procurement of this knowledge. The knowledge that is to be gained really needs to come from the integration of experience with the understanding that comes from this framework. It greatest contribution to accident investigators, I believe, will not come from a check sheet but a new and expanded way of viewing the world with which they are so intimately familiar. And it should provide credence for at least reflecting, if not acting, on observations that don't make the apodeictic cut because in the cause-effect chain of reasoning they are out beyond the ambiguous scattering of initial conditions.

Specific Recommendations for MAC and the United States Air Force

With respect to policy recommendations, I am not naive nor idealistic enough to believe that this work will cause sufficient disorder in an agency as complex and powerful as the United States Air Force, or the Military Airlift Command for that matter, to bring about any significant changes in policy. In fact, what I have brought to light in this work is illustrated by a MAC accident that is now 16 years old. MAC is currently and justifiably revelling in its enormous logistical accomplishments in support of Desert Shield and Desert Storm.

But MAC is the flying arena I feel closest to and strongest about. We know that the accident that caused the tragic deaths of the McChord based 40641 crew was not an event in and of itself that caused sufficient disorder in MAC for any significant improvement at the policy level. With the contextual understanding we have from this work, we are enlightened enough to know not to expect this. The basis of this enlightenment is not cynicism! It is an understanding of paradigmatic phenomena that leads to such results by normal people doing their best at their respective jobs.

No, I do not expect to change any policies. My hope is more humbly this: that pointing up the *paradigmatic nature* of this tragedy will somehow stimulate discourse in the Air Force community about the management of aviation safety as an integratal part of the Air Force mission. This accident, and perhaps many others as well, needs to be reexamined by policy makers at all levels for its *fundamental* surprize content.

The thinking needs to go well beyond the *situational* surprize of the specific accident and its surrounding apodeictic events. The mission-oriented culture of the Air Force will not change, nor should it. The job these dedicated people do for their country is phenomenal. For precisely these reasons there will always be another Lt Evans whose judgment must be considered within the cultural context. So it is only through such an approach that brings out that context that underlying policy inadequacies can come to light and thus be addressed.

A paradigmatic perspective can generate a reexamination of policies or regulations which are carried forward from one commander to the next; policies that carry forward under the watch of different commanders simply because the policies have long tenures -- "We've always done it that way -- and there's never been any problem." There's never been any problem because this information about the problem is systemically distorted. Sticking to apodeictic situational conclusions from accidents helps to sustain these policies. It helps the complex avoid having to mess with policies changes that would seem to cause "too much" internally generated disorder. These regulations and operating policies seem to carry a built-in impenetrable shield to externally generated disorder by virtue of their inclusive "official" policy statements that "safety is goal number one." This is why an understanding of the inadequacy of the goal paradigm in explaining organizational behavior is so important. Organizational complexes don't respond to "official goals," they respond to disorder. They only respond to an official goal if not doing so creates greater disorder than doing so. And when it comes to trade-offs, as we have seen, safety policies and goals just do not create enough disorder to dislodge policies that promote the more tangible aspects of availability -- policies such as the length of crew duty days, flight crew staffing and composition, mission scheduling, and so forth.

With the winding down of Desert Storm and the Administration's planned reduction in all branches of the military perhaps this is a good time for a new look. An examination of policies from the ground to the air under a new light. The loss of the MAC C-5 early on in Desert Shield would be another opportunity for fundamental reexamination -- another look for *fundamental surprize* content. My understanding from MAC crew members, although I have not verified this independently, is that the number one engine thrust reverser fully deployed at takeoff thrust on the roll. Simultaneously, the warning indicator which would have alarmed the crew failed. If that is true, even knowing nothing else, that makes it a paradigm of a "normal" system accident because it resulted from the unforeseen and incomprehensible interaction of two failures. But does the investigation fall into the trap of the *fundamental surprise error*? It would certainly cause the least organizational disorder to learn only the situational lessons from an examination of the surface events. What was the crew fatigue situation? Would an alert crew have had a better chance to perceive, comprehend and react quickly to the situation? Are there *any* policy implications which "set the stage" for this accident?

My comments and suggestions below, in fact any insights and lessons gained from this entire study, are presented in the spirit of furthering discourse, learning and positive improvement from all perspectives. Having been a MAC crew member I am sensitive to the context of the aircrews' flying job. Having been a decorated Air Force officer and combat veteran I am sensitive to the mission of the Air Force. As an expert in industrial and management engineering I am sensitive to the tough demands on the commanders and their staffs from the top level on down. These are the people in MAC who must manage this most complex logistics enterprise in a way that effectively and efficiently achieves its mission in support of the United States Armed Forces.

But the issue of improving flight safety in MAC does not have to come at the expense of the more tangibly experienced aspects of availability -- at the expense of accomplishing the mission. In fact it would actually enhance the agency's ability to accomplish its mission in a resilient and sustained fashion. The job of integrating policy changes which enhance flight safety, with the demands of accomplishing the mission just has to be given the appropriate priority from the top. Getting it on the agenda is the tough job. Figuring out *how* to do it is a relatively addressable problem.

The specific suggestions and recommendations I have are the following:[144]

1. **Reexamine the organizational structure for accident investigations.** The dual investigation process may still be appropriate to allow for candid comments from witnesses under protection of confidentiality. But the make-up of the Safety Investigation Boards and the Collateral Accident Investigation bodys need to be rethought. It is quite clear that conclusions which would tend to cause considerable disorder are not to be expected -- even if clearly warranted -- from investigating bodies whose composition is essentially from the orga-

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144 I have made no attempt to examine current policies. These recommendations are based on knowledge of policies that is somewhat dated. However, having talked with those who are knowledgable of the current Air Force and MAC operating environment, there is no reason to believe that things are fundamentally different.

nization which has responsibility for the operating policies that might be implicated. I know; it is tough for an organization to believe that it cannot examine itself openly and objectively. But that is simply a paradigmatic fact. It might happen; but because of the organization's *natural* tendency to avoid disorder and systemically distort information it is not to be expected.

2. **The Air Force safety community needs to open up its windows.** The community is steeped in the "technological guardianship" argument. It just doesn't wash. It perpetuates the systemic distortion of information and flight safety suffers because of it. Although it is important to protect confidentiality of witnesses, much can be disclosed and it would be healthy to do so. First, conclusions, findings and recommendations should be widely communicated and discussed. Supporting testimony and evidence could be easily sanitized of witnesses names/identities and technological/mission secrets, but nothing else, before it is made available. After such sanitization, all of this should be publically available information. The only reason it isn't is because of the potential disorder it may cause in the organization. Without some disorder generating scrutiny, however, there is no checks, no balance. It is obvious from the 40641 examination that it would be healthy for the Air Force to have some.

   It is understandable that this would be a bitter pill to swallow -- some might even think a poison pill. But that has to be weighed along with the benefit. Case studies of accidents like this one on 40641 would be a mechanism for continual never-ending quality improvement of the safety context, as well as the accident investigation process itself. It would invite research into management processes. (I can hear the windows slamming shut now!) Sure, it might make some commanders squirm but that is only if the organization is managed by fear. Rather, embedding such an approach in a culture that seeks continual process improvement, to draw a parallel from the well known needs of American industry for Total Quality Management, would lead it in the right direction. But that points to a paradigmatic examination of management processes in general and possible cultural readjustments which are difficult at best, even in the long run. Industries which are open and trying such cultural changes have a tough time climbing that hill. I don't know what the Air Force brass thinks of modern management philosphies such as TQM, but it might be worth considering in the broader context.

3. **The MAC Commander should commision a project to examine its scheduling and crew management policies from top to bottom with the intent of better integrating human factors knowledge with mission requirements.** This may be the most palatable recommendation and it would go a long way in demonstrating a sincere interest in improving the contextual stage upon which the crews perform their missions. MAC has responsibility for an enormously complex logistics mission, but this should not be an academic exercise in "optimal scheduling policy." In fact, pure academicians and operations research/systems analysts are ill equiped to perform such a study because their perspectives are simply too narrow. They are not engaged with the context of the aviation safety environment nor the management environment and thus would be susceptible to the pitfalls of an analytical functionalistic approach. The approach, if it is to be a serious one, needs to be truly interdisciplinary. A problem investigation team needs to be assembled which has

genuine participation from active crew members[145], management at appropriate levels, human factors expertise, MIS and expertise in modern management technology. Crew, organizational and mission impacts need to be examined *in context*. The results of the problem investigation would likely identify research opportunities for blending human factors considerations of long-haul transmeridian flight with scheduling and crew management. Information management implications, of course, would be crucial.

4. **Air crews should have a mechanism to influence policies which affect the safety context of their flying jobs.** One way to do this is to survey MAC crews as a part of the recommended study in 3, and then give them a chance to comment on policy recommendations before they are implemented. This kind of thinking may be foreign to the military but the upside potential is enormous. Instead of having the morale *busting* effect that the integral crew policy had when it was imposed from the top down as the Commander's response to an accident, it would have an enormously morale *boosting* effect because the crews would feel like they are a part of the policy making process that has an influence on their lives and the risks they are asked to take. It might be argued that crews already have an input through the chain of command but I doubt there are many line flying crew members who would believe that. And it also ignores the systemic filtering and distortion of information that is paradigmatic of organizations. *Real* concerns just don't don't arrive at the right organizational place in the same condition they left the person generating them. They get filtered in a way that is favorable to the current organizational arrangements.

   NASA crews now have considerably more involvement, review and say over policies which affect them. That is, they are more *engaged* with the broader context of their mission because of the paradigmatic impact of *Challenger*. Such management structures as well as others should be examined for ideas which would enhance crew engagement with the policy context of their jobs.

The temptation would be to reject these recommendations outright as naive and infeasible or impractical. This is the pitfall of technological guardianship. It is the same kind of argument that is used to reject the skeptical discourse about the SDI (the Strategic Defense Initiative or "Star Wars") and other such program. It is an argument for avoiding disorder and it goes something like this: "These are complex technical matters best left to the people in charge or the technical experts who already understand such needs and have responsibility for dealing with them."

145 That might be accomplished by having MAC line flying people select who *they* want to represent the crew perspective. A management decision to select "Col Joe" over here in Wing or Command staff because "he used to do a lot of flying and therefore ought to know a lot about flying" will not be successful. Col Pennella knew a lot about flying, even flew C-141s. The decision must come from the line crews.

Closing

In Chapter 1 I knocked on this door with an hypothesis that basically stated that our current approach to the explanation and understanding of aviation safety was sufficient. I characterized this approach as basically scientific in its nature and form, seeking cogent, rational and objective insight into the causes of aviation accidents or incidents and thus providing enlightened approaches for developing new technological solutions to "fix" the problems.

This work has not denied the necessity of and the value gained by this traditional approach for dealing with aviation safety. But the closing reflective comment needs to be its insufficiency. What the traditional approach points up as significant and worthy of investigation may just be the functional tip of the contextual iceberg.

ENDNOTES

Endnotes

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38. cf. the anthology edited by Imre Lakatos and Alan Musgrave. (1970). *Criticism and the Growth of Knowledge.*, Cambridge University Press.

39. Pitt, p6.

40. *ibid.*, p6.

41. *ibid.*, p7.

42. Borgmann, Albert. (1984). *Technology and the Character of Contemporary Life: A Philosophical Inquiry.* University of Chicago Press.

43. Leder, Drew. (Spring 1988). "The Rule of the Device: Borgmann's Philosophy of Technology." *Philosophy Today.* p17-29. In this 13 page review and critique of Borgmann's work, Leder describes it as: "not simply a major contribution to the philosophy of technology. It is a significant work for all those seeking insight into the texture of modern life: the machines which surround us, the way we utilize our leisure and labor time, the structure of our cities, the functioning of our political discourse and institi-tutions." ..."an important and original book ...[in which] Borgmann engages the relevant literature at length, including not only philosophers, but sociologist, political theorists, historians, psychologists and literary critics ...lending a scholarly depth and rigor." ..."Borgmann's discussion of technology is both analytically incisive and has the revelatory power of a fine work of art. For this reader, the technological landscape is ever transformed. Borgmann's work reminds us that philosophy is not simply a scholarly pursuit but has the power to engage and reveal the everyday world."

The significance of Borgmann's work is also underlined as it recently became the focus of a symposium sponsored by the Society for Philosophy and Technology which published several of the papers in its annual volume on research in philosophy and technology: Durbin, Paul T. (Ed.). 1988. "Technology and Contemporary Life." Reidel, Boston.

44. Borgmann, *Technology*, p19.

45. *ibid.*

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48. Hempel and Oppenheim (in Pitt's *Theories*), p9.

49. *ibid*, p10.

50. *ibid.*

51. Borgmann, *Technology*, p20.

52. *ibid.*, p13.

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55. *ibid.,* p121.

56. *ibid.*, p131

57. *ibid.*, p134.

58. *ibid.*, p14.

59. *ibid.*, p47, n10.

60. *ibid.*, p15.

61. Glass, Arnold L. and Keith J. Holyoak. (1986). *Cognition,* 2nd ed. Random House, New York.

62. *ibid.*, p15.

63. *ibid.*, p5.

64. cf. Sheridan, Thomas B. and W. R. Ferrell (1974). *Man-Machine Systems: Information, Control and Decision Models of Human Performance.* MIT Press, Cambridge, MA.; and also Rouse, William B. (1980). *Systems Engineering Models of Human-Machine Interaction.* North Holland, New York.

65. Rouse, *Systems*, p1.

66. *ibid.*, p2.

67. These relationships are expressed in terms of the prevailing "paradigms of modeling" -- those recognized areas of modeling achievement that have provided model problem-solutions for the community of modeling practitioners. These include: estimation theory; control theory; queueing theory; fuzzy set theory; and production systems, pattern recognition, and markov chains -- the chapter titles of Rouse's book. As established approaches to the "normal science" of mathematical modeling these classes of models are part of its paradigm (as we have used the term thus far). Rouse's use of the term paradigm (p9), in particular "the status of a paradigm," is an illustration of the confusion that has beset this term. Rouse misinterprets Kuhn's notion of paradigm as a micro-concept and claims that only the servomechanism "analogy" of control theory truly has achieved the status of a "paradigm" for modeling the human (in this case, as an error-nulling device).

First of all, Kuhn's concept is not meant to deal with "micro-changes" within a discipline. Carrying Rouse's use to an extreme, of course, we would be wondering whether a simple proportional relationship has "reached the status of a paradigm" of whatever field, whereas Kuhn often talks of a single paradigm (or at most a few) that an entire field operates under; that being the accepted problems, methods and approaches of the field that are implicitly defined by universally recognized achievements (Einsteinian mechanics, for example, as opposed to Newtonian mechanics) (see Kuhn, *Structure, passim*). Scientists "pattern" their work and thinking after these "exemplars." "Though there have been important changes in my position during the seven years since my book was published, the retreat from a concern with macro- to a concentration on micro-revolutions is not among them." (Kuhn, "Reflections on My Critics", In: Lakatos and Musgrave (Eds.), *Criticism and the Growth of Knowledge,* Cambridge), p249.

Thus specific analogies or mathematical models are not paradigms (in Kuhn's sense) as they are all available as potential approaches to problems, whether or not much success has been achieved with any given one. In Kuhn's clarification of his concepts he refers to these as part of the "disciplinary matrix" of the field. See Linstone's usage of the term earlier in this chapter and my more detailed discussion in later.

68. *ibid.*, p2.

69. *ibid.*, p7.

70. *ibid.*, p9.

71. *ibid.*, p12.

72. See also Brody, *Readings*, p2-6.

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74. *ibid.*, p53.

75. *ibid.*, p64-65.

76. *ibid.*, p66.

77. *ibid.*, p65.

78. *ibid.*, p73, n17.

79. *ibid.*, p60.

80. *ibid.*, p71-72.

81. Borgmann, *Technology*, p27.

82. *ibid.*, p21.

83. Borgmann, Albert. (1976). "Mind, body, and world." *Philosophical Forum.* v8, n1 (Fall). p68-86. See p80.

84. *ibid.*, p22.

85. *ibid.*, p23.

86. *ibid.*, p24 and the literature there cited.

87. *ibid.*, p25.

88. *ibid.*, p24 and the literature there cited.

89. *ibid.*, p27 & 29.

90. *ibid.*, p31.

91. *ibid.*, p179.

92. *ibid.*, p70 and literature there cited.

93. *cf.* ATA, *National Plan,* and FAA, *Cockpit Human Factors,* cited in Chapter 1; see especially the program elements in the ATA plan and the table of contents in the FAA report.

94. Perrow, Charles. (1983). "The Organizational Context of Human Factors Engineering." *Administrative Science Quarterly*, v28, p521-541.

95. Bella, David. (October 1987). "Organizations and Systematic Distortion of Information." *Journal of Professional Issues in Engineering,* v113, no 4, p360-371.

96. Greene, "Contextual Aspects of Human Factors," p1.

97. *ibid.* De Greene publishes in a wide variety of journals calling for a "new paradigm" for the behavioral and social sciences. He points out serious problems with current approaches that he says have been modeled after the Newtonian paradigm of physics. He highlights the need to consider contextual issues. But, ironically, his work represents a stricking example of the continued effort of social science to pattern itself after the physical sciences.

He believes that the behavioral and social sciences just haven't caught up with modern physics and it is there -- in field theory -- that he believes he has discovered the appropriate Kuhnian-paradigm which will unlock the mysteries of the social realm. "...recent advances in physics and qualitative mathematics may bring new life to field theory in social science." Critical phenomena, for example, is one of these he is developing based on modern physics. "Critical phenomena may provide a model for social systems. ...Critical phenomena are due to strongly nonlinear interactions among atoms. Critical points also define temperatures above which alloys lose their ordered arrangement among atoms, superconductors lose the property of superconductivity, and ferromagnets lose their magnetism." See De Greene, Kenyon B. (1978). "Force fields and emergent phenomena in sociotechnical macrosystems: Theories and models." *Behavioral Science*, v23. p1-14. See also: De Greene. (1990). "The turbulent-field environment of sociotechnical systems: Beyond metaphor." *Behavioral Science,* v35. p49-59. and De Greene. (1990). "Supplementary Systems Paradigms for Different Stages of Societal Evolution with Special Reference to War and Peace." *Systems Research*, v7, n2. p77-89.

98. *ibid.*, p2-3.

99. Hoos, I.R. (1972). *Systems Analysis in Public Policy.* University of California Press. Berkeley.

100. *ibid.*, p25.

101. *ibid.*, p26 & 179.

102. Borgmann. "Mind, body, and world." p80.

103. *ibid.*, p178.

104. *ibid.*, p169-182.

105. *ibid.*, p169.

106. *ibid.*, p178.

107. *ibid.*, p181.

108. Borgmann, *Technology,* p72.

109. *ibid.*, p73.

110. *ibid.*, p74.

111. Durbin, Paul T. (1988). *Dictionary of Concepts in the Philosophy of Science.* Greenwood Press, N.Y. p221-224.

112. *ibid.*, p4.

113. *ibid.*, p73.

114. Minas, Anne C. (1977). "Why 'Paradigms' Don't Prove Anything." *Philosophy and Rhetoric,* v10, p217-31.

115. Masterman, "The Nature of a Paradigm" (cited above), p65.

116. Borgmann, *Technology,* p75 and n9, p263.

117. *ibid.*, p75-76.

118. *ibid.*, p75, see also n8, p263.

119. Cedarbaum, Daniel G. (1983). "Paradigms." *Studies in History and Philosophy of Science,* v14, no 3, p173-213. See in particular p174-5.

120. *ibid.*, p174.

121. Kuhn, Thomas S. "Reflections on My Critics." In: Lakatos and Musgrave, p231-78. See specifically p234.

122. Letter from James B. Conant to T.S. Kuhn, 5 June 1961, cited by Cedarbaum, p173-4.

123. "[This paper] is written on the assumption that T.S. Kuhn is one of the outstanding philosophers of science of our time." Masterman, p59.

124. Masterman, p61. See also Cedarbaum, *passim*.

125. Cedarbaum, p175.

126. Kuhn, Thomas S. (1977). *The Essential Tension: Selected Studies in Scientific Tradition and Change.* University of Chicago Press. This is a collection of Kuhn's works; see the Preface, p xvii.

127. Cedarbaum, p176-7. Cedarbaum has made a thorough effort to reserect the correct use of the term 'paradigm' as it was introduced and used earlier by these three philosophers, and originally intended to be used by Kuhn. Cedarbaums research includes not only a thorough examination of early literature but personal files and papers by Kuhn and others, as well as a personal interview with Kuhn.

128. Kuhn, *Essential,* p xxi.

129. Kuhn, Thomas S. "Logic of Discovery or Psychology of Research?" In: Imre Lakatos and Alan Musgrave (Eds.). (1970). *Criticism and the Growth of Knowledge.* Cambridge University Press. p1-23. See specifically p2.

130. Kuhn, Thomas S. "Second Thoughts on Paradigms." In: Suppe, Frederick (Ed.). (1974). *The Structure of Scientific Theories.* University of Illinois Press, Chicago. p459-482. See in particular p460.

131. Kuhn, Thomas S. "Reflections on My Critics." In: Lakatos and Musgrave, p231-78. Specifically see p 271.

132. Kuhn, Thomas S. "Postscript-1969." In: Kuhn. (1970). *The Structure of Scientific Revolutions.* 2nd Ed. The University of Chicago Press. p174-210. See specifically p175.

133. Borgmann, *Technology*, p73.

134. Borgmann, Albert. 1978. "The Explanation of Technology." *Research in Philosophy & Technology*. v1, p99-118. See p110 for the specific quote.

135. Borgmann, *Technology*, p73.

136. cf. Pitt, Joseph C. and Marcello Pera (Eds.). (1987). *Rational Changes in Science: Essays on Scientific Reasoning*. D. Reidel Publishing, Boston. Also, of course, we have already refered to Borgmann's and Cedarbaum's works above. See also, Gutting, Gary .(1980). *Paradigms and Revolutions*. University of Notre Dame Press; and Kisiel, Theodore .(1982). "Paradigms," *Contemporary Philosophy: A New Survey*, v2, p87-110.

137. Borgmann, *Explanation*, p110 and the notes and literature cited therein.

138. Kisiel, Theodore. (1982). "Paradigms." In: *Contemporary Philosophy: A New Survey*. v2, p87-110. See in particular p88 and 90.

139. Douglas Lee Eckberg and Lester Hill, Jr. (1980). "The Paradigm Concept and Sociology: A Critical Review." In: Gutting, Gary. (Ed.) *Paradigms and Revolutions: Appraisals and Applications of Thomas Kuhn's Philosophy of Science*. University of Notre Dame Press. p117-8 and 122.

140. De Mey, Marc. (1982). *The Cognitive Paradigm*. D. Reidel Publishing, Boston. p104.

141. The scientific facts of this discussion and the quotes come from Mack, Richard N. (1981). "Invasion of *Bromus Tectorum* L. into Western North America: An Ecological Chronicle." *Agro-Ecosystems*, v7, p145-165, *passim*.

142. Karl Popper uses the term "framework" when discussing this mental set, which is what I prefer also to avoid confusing the different connotations of paradigm. See: Popper, Karl. 1987. "The Myth of the Framework." In: Pitt, Joseph C. and Marcello Pera (Eds.). *Rational Changes in Science: Essays on Scientific Reasoning*. Reidel, Boston. p35-62.

143. Incommensurability was one of Kuhn's central theses. See also: Bella, David A. and K.J. Williamson. (1976). "Conflicts in Interdisciplinary Research." J. Environmental Systems. v6(2), p105-124.

144. De Mey, *Cognitive Paradigm*, p98.

145. *ibid.*, p100.

146. *ibid.*, p97-98.

147. Angeles, Peter A. (1981). *Dictionary of Philosophy*. Barnes and Noble Books, New York. p47.

148. Harris, Errol E. (1970). *Hypothesis and Perception: The Roots of Scientific Method*. George Allen & Unwin Ltd, New York. See his section on context, p251-256.

149. *ibid.*, p256, emphasis added.

150. Durbin, Paul T. (1988). *Dictionary of Concepts in the Philosophy of Science*. Greenwood Press, New York. Paul Durbin, in this wonderful collection of brief (one to four page) summaries of controversial concepts in the history and philosophy of science, states that since "concept" is a synonym for the object of (self-) conscious knowledge, "it [the term "concept"] is among the most controversial of concepts in the Western philosophical tradition," and he cross-references 29 other concepts in his collection that have been entangled with it. Durbin gives nice historical perspectives of lines of thought on each concept citing key literature.

151. Heath, P.L. "Concept." In: Paul Edwards (Ed.) .(1967). *The Encyclopedia of Philosophy*. The Macmillan Co., New York. p177-180.

152. *ibid.*, p178.

153. *ibid.*, p179.

154. De Mey, Marc. (1982). *The Cognitive Paradigm*. D. Reidel Publishing, Boston. See specifically p8.

155. *ibid.*, p15.

156. *ibid.*, p9.

157. *ibid.*, p15-16, original italics.

158. *ibid.*, p4, original italics.

159. *ibid.*, p21.

160. Kuhn, Thomas. (1970). *The Structure of Scientific Revolutions.* 2nd Ed. The University of Chicago Press.

161. cf. Suppe, Frederick. (1989). *The Semantic Conception of Theories and Scientific Realism.* University of Illinois Press, Chicago.

162. Kuhn, *Structure*, p *viii*.

163. *ibid.*, p44.

164. *ibid.*, p24.

165. Sternberg, Robert J. (March/April, 1986). "Inside Intelligence." *American Scientist.* v74, n2, p137-143.

166. See Dreyfus, Hubert and Stuart E. Dreyfus. (1986). *Mind Over Machine: Putting Computers in Their Place.* Free Press. New York.

167. DeGreene, Kenyon B. (September 1990). "Contextual Aspects of Human Factors: The Case for Paradigm Shift." *Human Factors Society Bulletin*. v33, n9, p1-3.

168. March, James and Herbert Simon. (1958). *Organizations.* John Wiley, New York.

169. Perrow, Charles. (1984). *Normal Accidents: Living with High-Risk Technologies.* Basic Books, New York. Perrow reviews the pertinent literature here; see his section "Three Rationalities," p315-321.

170. *ibid.*, p315-324.

171. Graziano, Loretta. (1985). "The Policy Relevance of Human Cognition: An Analytical Framework." *Et cetera,* v42, n2. p141-154.

172. cf. Ries, Al and Jack Trout. (1981). *Positioning: The Battle for Your Mind.* McGraw-Hill, New York.

173. *ibid.*, p3,5-6.

174. Graziano, *Policy Relevance*, p143,145.

175. *ibid.*, p146.

176. Allison, Graham T. (1971). *Essence of Decision: Explaining the Cuban Missile Crisis.* Little, Brown and Company, Boston.

177. Perrow, Charles. (1984). *Normal Accidents: Living With High-Risk Technologies.* Basic Books, New York. See p322.

178. Bruner, Jerome S. and Leo Postman. (December, 1949). "On the Perception of Incongruity: A Paradigm." *Journal of Personality*. v18, n2, p206-223.

179. *ibid.*, p220.

180. See Reason, James. (1990). *Human Error.* Cambridge University Press. p89 and 169.

181. *ibid.*, p221.

182. Postman, Leo and Jerome S. Bruner. (1948). "Perception Under Stress." *Psychological Review.* v55, p314-323.

183. Bruner and Postman. "Incongruity." p221.

184. Kuhn. *Structure*. p84-85.

185. Popper, Karl. (1987). "The Myth of the Framework." In: Pitt, Joseph C. and Marcello Pera (Eds.). *Rational Changes in Science.* Reidel, Boston. p35-62.

186. *ibid.*, p35.

187. *ibid.*, p36.

188. *ibid.*, p36.

189. *ibid.*, p52-53.

190. *ibid.*, p58.

191. *ibid.*, p57.

192. Rouse, William B. and Sandra H. Rouse. (July/August 1983). "Analysis and Classification of Human Error." *IEEE Transactions on Systems, Man, and Cybernetics.* v13, n4, p539-549.

193. *ibid.* , p541.

194. *ibid.*, p539.

195. Morgan, Clifford T., Jesse S. Cook, Alphonse Chapanis, Max W. Lund (Eds.). (1963). *Human Engineering Guide to Equipment Design*. McGraw Hill, New York. Quote is from the book cover jacket.

196. Meister, David and Gerald F. Robideau. (1965). *Human Factors Evaluation in System Development.* John Wiley & Sons, New York. p3.

197. Bella, David. "Catastrophic Possibilities of Space-Based Defense." In: Durbin, Paul T. (Ed.). (1989). *Philosophy of Technology: Practical, Historical and Other Dimensions.* Kluwer Academic Publishers, Boston. p27-40.

198. Perrow, Charles. (1983). "The Organizational Context of Human Factors Engineering." *Administrative Science Quarterly.* v28: p521-41.

199. Perrow, Charles. (1984). *Normal Accidents: Living With High Risk Technologies.* Basic Books, New York.

200. Bella, David. (in press). Technology and Democracy. A paper to be presented in Prague, July 1990.

201. Kuhn. *Structure.* p37.

202. Perrow, Charles. (1984). *Normal Accidents: Living with High-Risk Technologies.* Basic Books, Boston.

203. *ibid.*, p5-8.

204. *ibid.* p4-5.

205. *ibid.*, p7.

206. *ibid.*, p7-8.

207. *ibid.*, p8.

208. *ibid.*, p60-61, and 348.

209. Zhores, Medvedev. (1990). *The Legacy of Chernobyl.* Norton, N.Y. p22.

210. *ibid.*, p21-22.

211. Perrow. *Normal Accidents.* p5.

212. Perrow. *Normal Accidents.* p62-100.

213. *ibid.*, p63.

214. *ibid.*, p66.

215. *ibid.*, p70.

216. This is what happened to the Eastern Airlines L1011 that crashed in the Everglades in 1972. See NTSB. (1973). Aircraft accident report. Eastern Airlines, Inc., L-1011, N310EA, Miami, Florida, December 29, 1972. (NTSB-AAR-73-14). Washington, DC: National Transportation Safety Board.

217. *ibid.*, p71.

218. *ibid.*, p92.

219. *ibid.*, see p78 for further discussion on the use of these terms.

220. *ibid.*, constructed from the summary on p93.

221. See La Porte, T.R. and P.M. Consolini. (1989). "Working in practice but not in theory: theoretical challenges of high reliability organizations." Proceedings of the Annual Meeting of the American Political Science Association, 1-4 September, Washington, D.C., as well as Perrow for discussion on the effective organization of Air Traffic Control.

222. Borgmann, Albert. (1984). *Technology and the Character of Contemporary Life: A Philosophical Inquiry.* University of Chicago Press.

223. Bella, David. (1990). "Existentialism, Engineering, and Liberal Arts." *Journal of Professional Issues in Engineering.* v116, n3 (July). p307-319.

224. Bella. "Existentialism." p317.

225. This material is drawn from unpublished lecture notes by Albert Borgmann for a course titled "Philosophy of Technology," University of Montana, 1980; as well his 1984 book, *Technology*, cited above.

226. *The Sunday Oregonian*. (February 17, 1991). "Face-to-face talk becomes casualty in electronic offices." Original source article from *Knight-Ridder News Service*.

227. Ullmann, Owen. (January 27, 1991). "Instant TV changes White House beat: Electronics' ascendency, growth of press corps alter relationship." *The Sunday Oregonian*, p C1. Original article source is *Washingtonian Magazine*.

228. Rosenstiel, Thomas B. (January 27, 1991). "CNN New Channel for Diplomacy." *The Sunday Oregonian*, p C1. Original article source is the *Los Angeles Times*.

229. The last third of Borgmann's book deals with this aspect of technology, but we will not consider it further at this point.

230. See the introductory paragraphs of Borgmann, Albert. (1972). "Orientation in Technology." *Philosophy Today*, v16, n2 (Summer). p135-147.

231. Borgmann, Albert. (1978). "The Explanation of Technology." In: *Research in Philosophy & Technology*. v1, p99-118.

232. See Borgmann, Albert. (1973). "Functionalism in Science and Technology." In: *The Proceedings of the XVth World Congress of Philosophy*, v6, p31-36. and Borgmann, "The Explanation of Technology." p104-105.

233. Borgmann. "Explanation." p110.

234. *ibid.*, p111.

235. *ibid.*

236. *The Sunday Oregonian*. (December 9, 1990). "Building industry brains chipping away at perfecting electronic 'smart house'."

237. *The Sunday Oregonian*. (February 17, 1991). "Future forecast: High tech shifts to high gear for '90s." Original source article from *Los Angeles Times Syndicate*.

238. Borgmann. "Explanation." p111.

239. See Borgmann, "Functionalism."

240. See Borgmann. "Orientation." p140.

241. *ibid.*, p140.

242. *ibid.*

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247. Borgmann. "Explanation." p111.

248. Borgmann. *Technology*. p105-106.

249. Rogers. "Right Button." p46.

250. *ibid.*

251. Borgmann. *Technology*. p77.

252. Bella. "Existentialism." p311.

253. Steele, Lowell W. (1990). *Managing Technology*. p8.

254. Bella. "Existentialism." p314.

255. *ibid.*, p314.

256. Borgmann. *Technology*. p116.

257. *ibid.*

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259. *ibid.*

260. *ibid.*

261. *ibid.*

262. *ibid.*

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264. *ibid.*, p199 and 194.

265. Wiener, Earl L. (1989). *Human Factors of Advanced Technology ("Glass Cockpit") Transport Aircraft.* NASA Contractor Report CR-177528. NASA-Ames Research Center, Moffett Field, CA.

266. Borgmann, "Reflections," p194,195,196, and 197.

267. Wiener, Earl L. (1988). "Cockpit Automation." In: Wiener, Earl L. and David C. Nagel (eds.). *Human Factors in Aviation.* Academic Press, New York. p433-461. See p435.

268. Wiener, Earl L. and R. E. Curry. (1982). "Flight-Deck Automation: Promises and Problems." In: Hurst, Ronald and Leslie R. Hurst (eds.). *Pilot Error: The Human Factors.* 2nd ed. Jason Aronson, New York. p67-86. See p69.

269. The figure is adapted from Borgmann's unpublished notes cited above.

270. See *The American Heritage Dictionary of the English Language*. Houghton Mifflin Co. Boston; see also Borgman, "Technology and Reality," p59, for a short and interesting ontological comparison of travel by jet and pretechnological travel.

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280. *ibid.*

281. Perrow, *Normal Accidents,* p162.

282. *ibid.*, p162-163.

283. *ibid.*, p163-168.

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285. Altschuler and Elsayed, *Simultaneous ILS: Literature Survey,* p1.

286. Dunn, "NASA still struggles."

287. Altschuler and Eslayed, *Simultaneous ILS: Literature Survey*, p1.

288. *ibid.*, p3.

289. *ibid.*, p22.

290. *ibid.*

291. See Perrow, *Normal Accidents*, p305-315, for a head-on bashing of the subject.

292. McNeil/Lehrer New Hour. (December 10, 1990). Special indepth report on runway safety.

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295. *ibid.*, p88.

296. *ibid.*, p91.

297. *ibid.*

298. *ibid.*, p92.

299. *ibid.*

300. *ibid.*, p107.

301. Rouse, William B. (1988). "Adaptive Aiding for Human/Computer Control." *Human Factors,* v30, n4, p431-443. See specifically p441.

302. Rouse, *et al.*, "Architecture." p112.

303. *ibid.*, p117.

304. Borgmann, "Functionalism," p35.

305. For a philosophical discussion of this see Florman, Samuel C. (1976). *The Existential Pleasures of Engineering.* St. Martin's, Inc. New York.

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307. See Bella, David and Jonathan King. (1989). "Common Knowledge of the Second Kind." *Journal of Business Ethics,* v8, p415-430.

308. Bella, "Existentialism," p315; quote from Barrett, William. (1978). *The Illusion of Technique.* Anchor Press, Garden City, NY.

309. Bella, "Existentialism," p317-318.

310. Bella, David. (in press). "Technology and Democracy." A paper presented in Prague, July, 1990.

311. Perrow, Charles. (1979). *Complex Organizations: A Critical Essay (2nd ed.).* Scott, Foresman & Co., Glenview, IL. See p156.

312. Perrow, Charles. (1961). "The Analysis of Goals in Complex Organizations." *American Sociological Review,* v26, n6 (December), p854-866. See specifically page 854.

313. Sheridan, Thomas. (1989). "Designing Complex Technology: Understanding It as of, by, and for People." *Technological Forecasting and Social Change.* v36. p89-97. See p89.

314. Perrow. *Complex Organizations.* Preface to the 2nd ed. See also p155-157 for other points brought out in this discussion.

315. Georgiou, Petro. (1973). "The Goal Paradigm and Notes Towards a Counter Paradigm." *Administrative Science Quarterly,* v18, n3 (September), p291-310.

316. *ibid.*, p297.

317. *ibid.*, p291. Georgiou describes this in the form of a Kuhnian paradigm, denoting an overwhelming conceptualization that no one individual developed, but that has appeared throughout various studies, from Weber and Taylor to the present, representing the dominant framework from which organizations have been viewed.

318. *ibid.*, p292.

319. *ibid.*, p299.

320. *ibid.*, p308.

321. *ibid.*, p306.

322. Bella, David. (1986). "The Organizational Complex and Its Information." Engineering Experiment Station, Oregon State University, Corvallis, OR. 32p. and Bella, David. (1987). "Organizations and Systematic Distortion of Information." *Journal of Professional Issues in Engineering.* v113, n4 (October), p360-371. For additional application, see also Bella, David. (1987). "Nuclear Deterance: An Alternative Model." *IEEE Technology and Society Magazine,* v6, n2 (June), p18-23.

323. Georgiou, "Goal Paradigm," p306.

324. Sonnenfeld, Jeffrey. (1981). *Corporate Views of the Public Interest: Perceptions of the Forest Products Industry.* Auburn House, Boston.

325. Bella. "Organizational Complex." p2.

326. Bella. "Organizational Complex." p1-8, and passim. See also the numerous supporting citations in Bella's work.

327. See *ibid.*, p10-14, for details.

328. See *ibid.*, p14, and the references there cited.

329. See *ibid.*, p15, and the references there cited.

330. See Bella. "Systematic Distortion," cited above.

331. See Bella, "Organizational Complex," p17, and the literature there cited.

332. See Turner, Barry M. (1976). "The organizational and interorganizational development of disasters." *Administrative Science Quarterly,* v21, p378-397; Reason, James. (1990). "The contribution of latent human failures to the breakdown of complex systems." *Philosophical Transactions of The Royal Society of London,* v327, p475-484; and Reason, James. (1990). *Human Error.* Cambridge University Press, see in particular Chapter 7, p173-216.

333. Feggetter, A.J. (1982). "A method for investigating human factor aspects of aircraft accidents and incidents." *Ergonomics,* v25, n11, p1065-1075; see specifically p1065.

334. Perrow, Charles. (1983). "The organizational context of human factors engineering." *Administrative Science Quarterly,* v28, p521-541; see specifically p530.

335. Vaughan, Diane. (1990). "Autonomy, Interdependence, and Social Control: NASA and the Space Shuttle *Challenger.*" *Administrative Science Quarterly,* v35, p225-257; see specifically p231.

336. Feggetter, "A method for investigating," p1065.

337. *ibid.*, p1066.

338. See Perrow, "Organizational Context," p525.

339. See Vaughan, "Space Shuttle *Challenger,*" p254; emphasis added.

340. *ibid.*, p254-256.

341. Reason, *Human Error.*

342. Reason, "Latent human failures," p1065.

343. Reason, *Human Error,* p212-213; part of Reason's quote comes from Lanir, Z. *Fundamental Surprise.* Eugene, OR. Decision Research, 1986.

344. Reason, *Human Error,* p214; quoting from: Woods, David. (1987). "Technology alone is not enough." In: R. Anthony (Ed.). *Human Reliability in Nuclear Power.* London: IBC Technical Services.

345. Reason, *Human Error*, p214.

346. Vaughan, "Space Shuttle *Challenger*," p232-233.

347. *ibid.*

348. *ibid.*, p228.

349. *ibid.*, p228-229.

350. *ibid.*, p229.

351. Personal communication; and also in Bella, David and Peter Klingeman. (1988). "Failures in Technological Systems." OSU Natural Resources Policy/Analysis Center Risk Assessment Program, Corvallis, OR.

352. Bella and Klingeman, "Failures," p4.

353. For details see Vaughan, "Space Shuttle *Challenger*."

354. *ibid.*, p5-6.

355. In all fairness to Boeing, Perrow does point out that, although there was no designated human factors group on the 747 design effort, there was significant human factors input on the 757 and 767 flight deck design. See Perrow, "Organizational Context," p532; and *Aviation Week*, "Human Factors Research Aids Glass Cockpit Design Effort." August 7, 1989, p34-36. But culturally it was, perhaps, the exception that proved the rule. It is from this effort that Perrow got one of the examples to illustrate his point. It relates to the difficulty a human factors engineer had in convincing the design engineers that the knobs on the VOR radio were too difficult to turn. It was easy for the design engineers (holders of the technical power and influence) to reject the argument without supporting quantitative data. Even when subsequently collected data demonstrating the knob could only be turned by a "50 percent man" or a "25 percent woman," the argument was still rejected. It was not until after data was collected on several older models (747's, 737's, and 727's -- "we've always lived with it before" thinking) "proving" that the VOR knobs were significantly harder to turn than any other knobs on all those airplanes, that the design engineers agreed to do something about it. It took that sort of effort to overcome the *opinion* of the design engineers that the knobs were not a problem. See Perrow, p529.

Perrow's article is somewhat dated at this point; the more recent *Aviation Week* article notes that "human factors analysis is becoming increasingly important in the design of automated cockpits and the development of related operational procedures." At the time of the article, Boeing's flight deck research group had three people with doctorates in human factors related discipline. Boeing human factors research is now headed by an internationally recognized expert, Dr. Curtis Graeber.

356. See Perrow, "Organizational Context," p529-530.

357. Allison, Graham T. (1971). *Essence of Decision: Explaining the Cuban Missile Crisis.* Little, Brown and Company, Boston.

358. The information in this section comes from Lt Colonel Michael Torgeson, Legal Advisor to the Directorate of Aerospace Safety, Headquarters Air Force Inspection and Safety Center (HQ AFISC/SEJ), (personal communication) and Torgeson, Michael G. (no date). *Aircraft Mishap Investigations and the Safety Privilege.* HQ AFISC/SEJ, Norton AFB, CA.

359. Letter from Senator Warren G. Magnuson to John L. McLucas, Secretary of the Air Force, dated April 1, 1975. Quotation comes from a news article cited below.

360. Letter from U.S. Air Force to Senator Warren G. Magnuson dated April 18, 1975. Quotation from news source cited below.

361. See TNT 5/4/75, cited below.

362. Letter from Brock Adams, United States Senate, to Secretary of the Air Force, June 29, 1990.

363. Letter from Colonel E.M. Hartung-Schuster, Chief of Staff, Department of the Air Force, Headquarters Air Force Inspection and Safety Center, to Mr. Garry Routledge, cc Senator Adams, August 3, 1990.

364. United States Air Force. (Accident date: 20 March 1975). *Collateral Investigation of Aircraft Accident Involving C-141A Serial Number 64-641*, Conducted under AFR 110-14. Located in the Warren G. Magnuson Accession, Accession No. 3181-5, Box 179, Folders 18-24. University of Washington Libraries Manuscript Collection.

365. United States Air Force. (Accident date: 20 March 1975). AFR 127-4 Safety Investigation Report No. 75-3-20-1: C141A, S/N 64-641; Part I.

366. This information comes from MAC Regulation 55-1. (5 April 1974). Chapter 2. and MAC Reg 60-2, Vol I (C1). (5 September 1974). Chapter 10. Note that comments refer to conditions and regulations that were in effect in the time frame of the 40641 accident.

367. This location and description is literally "off by a mile." Incident reports by Olympic National Park and verification with George Bowen, the Supervisory Park Ranger who coordinated much of the ground effort, place the location one mile west of Mt. Constance, above Home Lake on the northwest face of Inner Constance, whose peak rises to 7339 feet.

368. See PI 3/25/75, ST 3/25/75, and TNT 3/25/75b cited below.

369. See TNT 3/26/75a cited below.

370. The recovery operation is not documented in the Safety Investigation report. The source of the recovery effort information is Park Service Incident Reports and the personal notes of George Bowen. As an aside, Mr. Bowen told me (telephone conversation, 2/28/91) that pieces of the wreckage are still found occasionally, the most recent being one of the "dog tags" (identification tags) of the copilot which was found in the summer of 1988 by a backpacker.

371. These articles listed below are from three different news sources, with TNT referring to the *Tacoma News Tribune*, PI the *Post-Intelligencer* of Seattle, and ST the *Seattle Times*. The two investigative reporters, working independently, who brought so much more information to light regarding this accident were: Robert H. Mottram of the Tacoma News Tribune and Svein Gilje of the Seattle Times. It was Gilje's efforts at obtaining information through Air Force channels that precipitated Senator Magnuson's involvement and subsequent releases of information.

TNT 3/21/75a	McChord-bound plane, 16 aboard, missing in rugged Olympic Range
TNT 3/21/75b	Beeps signal crash
TNT 3/21/75c	C141s record pretty good: Starlifter known as workhorse of airlift command
TNT 3/22/75	No sign of life at Starlifter crash site
TNT 3/23/75a	Snow delays body recovery
TNT 3/23/75b	Why was C-141 flying so low?
TNT 3/23/75c	C-141 crash victims identified
TNT 3/24/75a	Air-control mistake sent 16 to icy death
TNT 3/24/75b	Mourners fill McChord Theater
TNT 3/24/75c	C-141 crash left seven widows
TNT 3/25/75a	A moment of confusion -- and 16 die
TNT 3/25/75b	Fatal last minutes for 16 recorded on FAA tape
TNT 3/25/75c	Search party at crash scene forced to quit
TNT 3/26/75a	Crew's errors may have contributed to C141 crash
TNT 3/26/75b	Computer 'down' as C141 crashed
TNT 3/27/75a	TNT Special Report: Airmen charge fatigue danger
TNT 3/27/75b	TNT Special Report: Crew sleepless 30-plus hours
TNT 3/27/75c	TNT Special Report: Air Force pressuring 'wave-making' flight personnel
TNT 3/27/75d	Air Force puts lid on news
TNT 3/27/75e	Plane possibly hit near crest
TNT 3/28/75a	MAC director's aide heads probe
TNT 3/28/75b	Air Force admits zippered-lip rule
TNT 4/2/75a	Search party at crash scene forced to quit
TNT 4/2/75b	Crash report secrecy: Magnuson wnats 'legal justification
TNT 4/4/75	Board in recess on crash probe
TNT 4/6/75	MAC's air hours exceed commercial
TNT 4/19/75	Promised to Maggie: Partial report of crash due
TNT 5/1/75	Camp set at sit of fatal C141 crash
TNT 5/4/75	Magnuson releases C-141 crash data
TNT 5/5/75	Colonel who spoke out give transfer
TNT 5/7/75	Weather delaying C141 camp
TNT 5/10/75	Park rangers camp at C141 crash site
TNT 5/20/75	Body of crash victim recovered from site
TNT 5/21/75	Recovered body that of airman
TNT 5/22/75	Ill-fated Starlifter had malfunctions before flight
TNT 5/27/75	Recovery of bodies possible
TNT 5/29/75	Two bodies found at C141 site
TNT 5/30/75	10 bodies left at site of crash

TNT	5/31/75	Two bodies identified: C141 crash probe to resume
TNT	6/3/75	Crash probe on; 7th body found
TNT	6/4/75	Recovery resumed at crash
TNT	6/5/75	Another C141 victim identified
TNT	6/6/75	8th body in crash recovered
TNT	6/9/75	9th body found at crash site
TNT	6/10/75	More bodies recovered
TNT	6/11/75	4 sad, grim job for AF rescuers
TNT	6/12/75	4 bodies in crash identified
TNT	6/13/75	Flight recorder of C141 recovered
TNT	6/17/75	C141 operation: Further salvage up to McChord
TNT	6/18/75	Crash tapes add nothing
TNT	6/19/75	Air Force tells names of crewmen
TNT	7/10/75	Aircraft's recorder no help
TNT	12/1/77	Rep. Dicks want full probe at McChord
PI	3/25/75	Tragic mixup blamed in jet crash
PI	3/30/75	Crew of crashed plane 'weary, inexperienced'
PI	4/1/75a	Maggie wants 'full report' on Air Force's C141 probe
PI	4/1/75b	Echoes of McChord crash: Near-collision being investigated
ST	3/21/75	McChord plane with 16 aboard crashes
ST	3/22/75a	Searchers landed near crash site
ST	3/22/75b	Plane occupants identified
ST	3/23/75	Weather halts recovery of plane victims
ST	3/24/75	Wrong orders may have doomed jet
ST	3/25/75	Fatal message: 'Maintain 5,000'
ST	3/28/75a	General's remarks on jet crash stir furor at McChord
ST	3/28/75b	General denies tirade over crash
ST	3/28/75c	Jet crash followed grueling day
ST	3/28/75d	Colonel rumored 'fired' in clash over jet crew's rest
ST	3/28/75e	Olympics not on military flight map
ST	3/30/75	McChord unit has about 25% of grounded pilots
ST	4/1/75a	Doomed plane didn't have problem with doors, pressure
ST	4/1/75b	Pilot asks inquiry after close call
ST	4/2/75	Senator wants report public
ST	4/4/75	First round of C-141 crash probe completed

372. Testimony and statements are contained in: *Collateral Investigation of Aircraft Accident Involving C-141A Serial Number 64-0641.* This is the investigation conducted from 27 March 1975 through 11 April 1975, at McChord AFB, WA, by Col Anthony J. Pennella; convened by Special Order A-26, dated 24 March 1975, Headquarters Military Airlift Command, Scott AFB, IL. The accident investigation was conducted in accordance with AFR 110-14, as supplemented, and by AFM 120-3. Listed here are the section tab identifier, the type of sworn statement (document or verbal testimony), the date the statement was take, the rank of the person giving the testimony, and the person's position or duty at the time of the investigation. Names are irrelevant and intentionally omitted.

Tab	Type	Date (1975)	Rank	Position or Duty
F	Verbal	4/1	Lt Colonel	Commander, 8th Military Airlift Squadron
G	Verbal	4/1	Lt Colonel	Operations Officer, 8 MAS
H	Verbal	4/1 & 4/9	Major	Asst Operations Officer, 8 MAS
I	Verbal	4/1	SMSgt	Standardization Load Master, 8 MAS
J	Verbal	4/1	Major	Standardization Navigator, 8 MAS
K	Verbal	4/3	Lt Colonel	On-scene Commander of Accident Investigation, 62 MAW
L	Verbal	4/2	Major	Standardization Navigator, Training, 62 MAW
M	Verbal	4/2	Major	Chief of Standardization, 8 MAS
N	Verbal	4/1	Major	Asst Standardization Navigator, 8 MAS
O	Verbal	4/3	Major	OIC Flight Simulation Section, 62 MAW
P	Verbal	4/1	Captain	Flight Examiner, 8 MAS
Q	Verbal	4/3	Captain	Flight Simulation Instructor, 62 MAW

R	Verbal	4/1	Captain	Asst Standardization Pilot, 8 MAS
S	Verbal	4/2	Captain	Flight Examiner Pilot, 8 MAS
T	Verbal	4/9	Captain	Aircraft Commander, 8 MAS
U	Verbal	4/9	Captain	Instructor Aircraft Commander, 8 MAS
V	Verbal	4/2	1 Lt	Aircraft Commander, 8 MAS
W	Verbal	4/2	1 Lt	Pilot, 8 MAS
X	Verbal	4/1	SMSgt	Standardization Flight Engineer, 8 MAS
Y	Verbal	4/2	SMSgt	Standardization Load Master, 8 MAS
Z	Verbal	4/1	MSgt	Asst Standardization Flt Eng, 8 MAS
AA	Verbal	4/8	Civilian	Area Officer Seattle ARTCC, FAA
BB	Verbal	4/9	Civilian	Asst Chief McChord RAPCON, FAA
CC	Memo	4/8	Major	Flight Examiner, 446 MAW (AFRes)
DD	Statement	no date	Major	CBPO (Personnel) Chief, McChord AFB
EE	Statement	4/4	Major	Officer Controller, McChord Operations Center (on duty at time of accident)
FF	Statement	3/21	Civilian	Seattle ARTCC Sector 3 Controller (Radar and Data combined, at time of accident), FAA
	Statement	3/21	Civilian	Seattle ARTCC Sector 2 Controller (Radar, at time of accident), FAA
	Statement	3/21	Civilian	Seattle ARTCC Sector 2 Controller (Data, at time of accident), FAA
	Statement	3/21	Civilian	Seattle ARTCC Supervisory Controller (Area A Team Supervisor at time of accident), FAA
	Statement	3/21	Civilian	Seattle ARTCC Asst Chief (on duty at time of accident), FAA
OO	Report	4/7	Captain	Claims Officer, McChord AFB
SS	Affidavit	4/4	Captain	Flight Surgeon, Chief of Aeromedical Services, McChord AFB
TT	Statement	4/7	Colonel	Deputy Commander for Maintenance
UU	Statement	4/4	Captain	Staff Weather Forecaster, McChord AFB
GGG	Telex	4/8	Major	JA (Legal Office), Yokota AB, Japan (preliminary statements taken from Maintenance Controller and Radar Repairman)
III	Memo	4/22	Lt Colonel	Chief, Contract Law Division, USAF Office of Staff Judge Advocate
JJJ	Statement	4/8	Major	Senior Controller, MAC Operations Center, Yokota AB, Japan
	Statement	4/3	TSgt	Senior Controller for Maintenance Control (on duty at time of 40641 Yokota service), Yokota AB
	Statement	4/4	Sgt	Radar Repairman (serviced 40641 radar), Yokota AB
	Statement	4/4	SSgt	Senior Controller, Yokota Tower (on duty at time of 40641 landing and departure)
	Statement	4/3	Sgt	Final Radar Controller, Yokota AB (on duty at time of 40641 approach and departure)
	Affidavit	4/7	WG-10	Aircraft Mechanic (on duty at time of 40641 service), Transient Alert Section, Tinker AFB, OK
	Affidavit	4/4	TSgt	Crew Chief, Tinker AFB Tower
	Memo	4/4	Major	DOCP Controller, Andersen AFB, Guam
	Memo	4/7	TSgt	Enroute Maintenance Technician, Andersen AFB
	Statement	4/16	Sgt	Air Traffic Control Operator, Clark AB, PI
	Statement	4/16	MSgt	Crew Chief, Clark Tower
	Statement	4/3	SSgt	Maintenance Technician, Clark AB (on duty at time of 40641 arrival)
	Statement	4/1	Captain	Base Billeting Officer, Clark AB

Statement 4/3 SSgt Automatic Flight Control Maintenance Shop, Clark AB

373. Tab FF, Sector 3 (R3/D3) Controller, 21 March 1975.

374. Tab FF, Sector 2 Radar Controller Statement, 21 March 1975.

375. Tab FF, Sector 2 Data Controller statement, 21 March 1975.

376. Tab FF, Area A Team Supervisor statement, 21 March 1975.

377. This development comes from philosopher Hubert L. Dreyfus, who has done extensive work in artificial intelligence, and operations research professor Stuart E. Dreyfus, both Professors at the University of California, Berkeley. Their specific paper from which these insights are drawn is adapted from their 1986 book: *Mind Over Machine: Putting Computers in Their Place.* Free Press, New York. The paper is: "From Socrates to Expert Systems: The Limits of Calculative Rationality." In: Carl Mitcham and Alois Huning (Eds.). 1986. *Philosophy and Technology II: Information Technology and Computers in Theory and Practice.* D. Reidel, Boston.

378. *Ibid.*, p117.

379. *Ibid.*, p118.

380. *Ibid.*, p118-119.

381. *Ibid.*, p119.

382. See ST 3/28/75a.

383. See ST 3/28/75c.

384. See ST 3/30/75.

385. See TNT 3/27/75b.

386. See PI 3/30/75.

387. See ST 3/28/75a and PI 3/30/75.

388. "I in no way used the word 'suicide' and I certainly did not say it was 'inexcusable to fly into that peak'," Gonge added. "What I did say is that they should have checked the altitude, they should have followed MAC procedures and checked the terrain map before accepting the clearance."

"...This was the first accident during my command here and, naturally, I wish for all of us that it will be the last. I tried to impress on everyone that 'you guys got to check first, that's what keeps us alive.' I said we just cannot understand why they (the C-141 crew) did not check (the map) first."

See ST 3/28/75b and PI 3/30/75.

389. See ST 3/28/75e.

390. See ST 3/28/75c.

391. See TNT 3/27/75b

392. See TNT 4/6/75.

393. See ST 3/28/75b.

394. The technical points introduced here are from: Graeber, R. Curtis. 1988. "Aircrew Fatigue and Circadian Rhythmicity." In: Earl L. Wiener and David C. Nagel (Eds.). *Human Factors in Aviation.* Academic Press, New York. p305-344. See Graeber's chapter for citations to any of the primary research results I introduce; I am drawing upon his summaries of the research.

395. *Ibid.*, p311.

396. *Ibid.*, p312.

397. *Ibid.*, p313.

398. *Ibid.*, p314.

399. *Ibid.*

400. *Ibid.*, p314-315.

401. *Ibid.*, p327.

402. *Ibid.*, p306 and 329.

403. *Ibid.*, p330.

404. *Ibid.*, p336.

405. See ST 3/28/75c.

406. See TNT 3/27/75a.

407. See TNT 3/27/75b.

408. *Ibid.*, p335.

409. Tab UU of the Colateral Investigation.

410. See TNT 3/27/75b.

411. See TNT 12/1/77.

412. See TNT 3/27/75c.

413. See TNT 3/27/75d.

414. See TNT 3/28/75b.

415. See TNT 4/2/75b.

416. See ST 3/28/75a.

417. See TNT 3/27/75a.

418. See ST 3/28/75d.

419. See TNT 5/5/75.

420. Wiener, Earl L. and David C. Nagel (Eds). (1988). *Human Factors in Aviation.* Academic Press. New York.

421. For more extended discussion and ramifications, see: Weiner, Carl L. (1987). "Fallible Humans and Vulnerable Systems: Lessons Learned From Aviation." In: Wise, J.A. and A. Debons (Eds.). *Information Systems: Failure Analysis.* NATO ASI Series, v F32. Springer-Verlag, Berlin. p163-181.

422. Graeber, "Aircrew Fatigue," p340.

423. cf. Weiner, Earl L. (1982). "Controlled Flight into Terrain Accidents: System-Induced Errors." In: Hurst, Ronald and Leslie R. Hurst (Eds.). *Pilot Error: The Human Factors.* Jason Aronson. New York.

424. Graeber, "Aircrew Fatigue," p340.

425. Graeber, "Aircrew Fatigue," p341.

426. Wilmot, William W. (1980). "Metacommunication: a re-examination and extension." In: D. Nimmo (Ed.). *Communications Yearbook 4.* Transaction Books, New Brunswick. p61-69.

427. *ibid.*, p61, 63.

428. A particularly good book that illustrates through many examples the paradigmatic nature commercial aviation safety, especially since deregulation, is that of airline pilot, accident investigator and aerospace law lawyer John Nance. Nance, John J. (1986). *Blind Trust.* Quill, New York.

429. Bella, David. (1990). "Democracy and Technology." A working draft of a paper Bella presented in Czechoslovakia, summer 1990.

430. *ibid.*, p26.

431. Chas Harral is a pilot with over 13,500 hours, a designated pilot examiner and director of the Harral Institute in Mesa, Arizona. He lectures on a variety of aviation and motivational subjects. His outstanding talk entitled, "Cockpit Mental Conditioning," was presented at the Eighth Annual Northwest Aviation Conference and Trade Show, Tacoma, Washington, February 9, 1991.

432. Sheridan, Thomas B. (1989). "Designing Complex Technology: Understanding It as of, by, and for People -- Some Dilemmas and What to Do About Them." *Technological Forecasting and Social Change,* v36. p89-97.

433. See Holling, C.S. (1977). "The Curious Behavior of Complex Systems: Lessons From Ecology." In: Linstone, Harold A. and W.H. Clive Simmonds (Eds.). *Futures Research: New Directions*. Addison-Wesley, Reading, MA. p114-129.

434. *ibid.*, p115.

435. ATA. (April 1989). *National Plan to Enhance Aviation Safety Through Human Factors Improvements.* Prepared by the Human Factors Task Force in Cooperation With Industry and Government. Air Transportation Association of America. Washington, D.C. p1.

436. *ibid.*, p2.

437. FAA. (April 1989). *Cockpit Human Factors Research Requirements.* Federal Aviation Administration. Washington, D.C.

438. Cohen, S.B. (May 7, 1990). "FAA Safety Indicators Program." TIMS/ORSA Conference, Las Vegas. See also: FAA. (November, 1989). "Aviation Safety Indicators: Concept Definition, Edition 1." Safety Indicators Division, Office of Safety Analysis, Associate Administrator for Aviation Safety.

439. *ibid.*, p3-2.

440. *ibid.*, p1-3.

441. See Rowe, William D. (1977). *An Anatomy of Risk.* John Wiley & Sons. New York.

442. Reason, James. (1990). "The contribution of latent human failures to the breakdown of complex systems." Philosophical Transactions of the Royal Society of London. v327, p475-484. See p476.

443. *ibid.*