CONTEMPORARY TECHNOLOGY AND ITS LIMITATIONS

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PREFACE

I had originally intended this document to be a paper within a technical journal, but I was unable to contain it within the 20-30 pages which most journals accept. Instead of breaking it into two or more sections, I decided to publish it in its present form. This document is a third revision. I plan to publish a fourth revision in the form of a book and I hope that such a book can benefit from discussions, comments, criticisms and suggestions from the readers of this report. My own thoughts are now directed primarily toward the last section of this report which I hope to develop more fully before the next revision.

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There are many people who deserve acknowledgment for their contribution to the thoughts expressed herein. I am most grateful to those people who have been able to see beyond the routines, techniques and demands of job and social role. These are people who can still see wonder, awe and meaning to life. Despite pressures, disappointments and their own doubts, they still approach life as a creative adventure.

David A. Bella

January, 1977

INTRODUCTION

There are few words which cause as much confusion, disagreement and conflict as the word, technology. It is with this understanding that I rather apprehensively state the purpose of this paper: to present a comprehensive and systematic view of contemporary technology from which its capabilities and limitations can be better understood.

I will examine present day technology as a rational discipline, particularly as it is practiced within engineering. I have drawn heavily from writings on "the history and philosophy of technology and science," however, my own approach is not historical. My point of view is that of a participant within technology and more specifically, within the profession of civil engineering. In the first section of this paper, I will briefly illustrate how I have used discussions with colleagues to develop a conceptual framework of disciplined technology. In the second section I will describe disciplinary communities and I will provide a general description of the bodies of knowledge held by such communities. In the third section I will present a general model of the behavior of disciplinary communities within technology. In the fourth section I will describe the common characteristics of technological communities and I will reason that these common characteristics provide a meaningful contemporary understanding of the word technology. Finally, I will discuss the limitations of technology.

WHY DO WE BELIEVE THAT F = MA?

I have never met an engineer or an advanced (two or more years of engineering education) engineering student who is not intimately familiar with the equation f=ma (Newton's second law of motion). Over the last several years I have conducted a simple study with engineering colleagues and students. First, I have asked them, "do you believe that f=ma?" I have never experienced any of them saying "no, I don't" or even, "I'm not really sure." Then, I asked, "why do we believe that f=ma?" The initial reply was often a nervous smile; the kind of smile that said "you are not supposed to ask that kind of question."

After some discussion, we always arrived at a set of answers which honestly reflected our actual experiences. "We believed that f=ma because the teacher said it was true." "We believed it because it said so in the textbook." "We believe it because lots of people use it." If it wasn't true, we reasoned, some of these people would have had problems, maybe serious problems, and we would have heard about it, or at least the person who wrote the book would have heard about it. None of us had heard that f=ma didn't work, at least in the application to typical engineering problems. These kinds of reasons form the basis of a multitude of our beliefs. We believe things largely because other people whom we identify as knowledgeable believe them and use them. We personally check out only a very small portion of that which we accept as being technically and scientifically sound. The equation, f=ma, has been successfully used for a long time by a very broad community of people. We have no reason to doubt their honesty or competence. Everyone whom we have met from this community believes it. Nobody seems to know of its failure. So we believe that f really does equal ma; if we didn't, we probably wouldn't be accepted within the community.

In teaching sophomore engineering mechanics several years ago, I assigned about 100 problems for each of two ten week courses. The texts were full of example problems and there were hundreds of unsolved problems for the student to work. Working these problems as an engineering student is an exhausting experience. The individual problems do not seem to be too important. There are problems concerning poles leaning against walls, balls bouncing off of tables, and blocks tipping over. However, through our repeated exposure to such problems, we assimilated general abilities, attitudes and beliefs. We gained "the ability to analyze any problem in a simple and logical manner and to apply to its solution a few, well-understood principles" (Beer and Johnston, 1962). We gained attitudes and beliefs which are able to justify explanations and descriptions. We gained a "feel" for good technological work.

Believing that f=ma is far more than faith in a simple equation. This equation is an inseparable part of a far more basic general knowledge. Without this broad general knowledge, f=ma is merely an arrangement of symbols. The concepts of force (f), mass (m) and acceleration (a), are not directly observable, they are not given to us by nature. They are mental constructs shared by a community of people. Such constructs serve to interpret observations and organize experiences (Barbour, 1971). But without the general knowledge of the community and without the fundamental attitudes, beliefs and commitments of the community, the symbols, the words and even the definitions, have little or no meaning.

COMMUNITIES AND PARADIGMS

Disciplinary Communities. The above discussion points to an essential characteristic of both disciplined technology and science; they are social enterprises (Schilling, 1958)(Polanyi, 1964)(Hagstron, 1965)(Layton, 1974). From our discussion of f=ma, we can see that technological beliefs gain their validity and acceptance through a community of individuals who employ these beliefs and communicate their experiences to each other. We will define such communities as disciplinary communities.

Common educational experiences and common topics of interest serve to identify disciplinary communities. Communication networks involving technical journals, workshops and technical meetings indicate a clustering of shared experiences and ideas and thus serve to identify them.

Shared standards and networks of peer review also provide community identity. Disciplinary communities, however, are seldom easily identified as distinct units. They can be visualized as social clusters with shared standards, models, ideals, commitments and experiences. Such clusters are real and identifiable yet they blend into and overlap with other clusters. These clusters evolve into new patterns and arrangements. Membership in these communities continually changes. We find communities within large communities. The problem of determining who really belongs within a particular disciplinary community is similar to the problem of who to invite to a wedding. You can easily identify a group of people who you should definitely include, and at the other extreme, you can identify a group of people who definitely do not belong. There are people, however, who do not fall into either of these two groups and it is with these that you encounter your biggest problem. You simply do the best that you can and accept the consequences.

The problems of precisely describing disciplinary communities should not serve as a reason for denying their importance. Human understanding is a social process and the social clusters which we have called disciplinary communities are important processors of technological and scientific understanding.

Paradigms. If you observe the literature (e.g. textbooks, journals) of any particular disciplinary community, if you examine their educational programs and if you examine the disciplined activities of community members, you will notice common attitudes, behaviors, topics and approaches which differ somewhat from other disciplinary communities. Electrical engineers do different things than organic chemists and they approach their work in different ways. Each disciplinary community identifies with a body of knowledge which provides disciplined guidance to community members. I will refer to such bodies of knowledge as paradigms. A discipline's body of knowledge, its paradigms, are integrated systems of things such as theories, concepts, laws, procedures, examples and models. Because of common paradigms, members of the same disciplinary community are able to discuss many topics which appear to be totally confusing to someone outside of the community. As an example, the Navier-Stokes equations familiar to most engineers within the area of fluid mechanics will be totally confusing to most microbiologists. Most of these same engineers, however, would find bacterial taxonomy to be overwhelmingly baffling. The paradigms of fluid mechanics, which contain the Navier-Stokes equations, are significantly different than the paradigms of microbiology, which contain bacterial taxonomy. Within each community, however, these paradigms provide a basis for rational discipline.

Members of a disciplinary community employ their paradigms (e.g. theories, models, laws, concepts, examples and procedures) to identify and solve problems. The paradigms also serve as a basis for evaluating each others work. Work is usually deemed reasonable when it conforms to the paradigms. Work which contradicts or violates the paradigms is usually considered unreasonable. Thus, the paradigms of disciplinary communities act as their guides and standards for selecting and evaluating problems, actions, approaches, explanations and observations (Kuhn, 1962). Without paradigms, disciplinary communities would have no basis for "doing things properly." Disciplinary education consists largely of the inculcation of the paradigms within the students through repetitive exposure until they "get it right."

Paradigms as Constellations. The word constellation has been used to describe a grouping of stars. There are a number of ways that you can observe a constellation. First, you can observe the individual component stars. Then, you might observe the arrangement of a few stars; several stars might be arranged in a straight line or an arc. Finally, you might observe an entire group of stars which might suggest to you an image such as a bear or a big dipper. A constellation, thus, can be viewed from different levels of resolution. These views differ in their relative degree of perspective and detail. From a fine resolution view, the individual components are seen; at an intermediate view, patterns and arrangements are seen; from the broadest view, an image is suggested or implied by the entire constellation. Paradigms can be considered as constellations of such things as procedures, examples, models, theories, concepts and commitments (Toulmin, 1972). Like constellations of stars, paradigms can be viewed from a spectrum of views. The need to view paradigms from different levels of resolution is of major importance. For our discussion, let us view paradigms from three levels of resolution: (1) the component level, (2) the schema level, and (3) the image level.

The component level view reveals high detail with little perspective. From this view of the paradigms, we see a variety of specific definitions, tools, techniques, procedures and examples which we will call components. Components may be expressed in handbooks, simple equations, tables or graphs. Textbooks contain illustrative components (e.g. example problems) of a discipline. Collectively, these components serve to identify the kinds of problems and questions which are of concern to the community, that is, they identify the community's domain (Bella and Williamson, 1976). Thus, the techniques for measuring dissolved oxygen and biochemical oxygen demand within water serve to identify kinds of water pollution problems of interest to environmental engineers. The community tolerates and even thrives upon some differences and disagreements at the component level (e.g. different ways of measuring dissolved oxygen). Such accepted differences, however, must not involve significant alterations of the paradigms as viewed at schema and image levels.

At the schema level, a broader view reveals theories, models, principles and concepts which provide descriptions and explanations of real world behavior. The schema level gives coherence to the component level: definitions intermingle into broader understandings; individual examples fall under general models, theories and principles; and techniques and procedures fall into patterns and arrangements. A relatively small number of theories and principles at the schema level are found to apply to a wide variety of specific situations. Dominant models are found which strongly direct a community's attitudes, questions and concerns, often for long periods of time. For instance, a conceptual model of water pollution published in 1925 (Streeter and Phelps, 1925) continues to have a dominating influence on environmental engineering. Consensus within the community with respect to the schema level is normally stronger than consensus with respect to the component level. Some disagreement is tolerated and some innovation is encouraged so long as it is compatible with the image view of the paradigms. Relative to the component level, the features of the paradigms seen from the schema level appear more general, fundamental and comprehensive and less specific, separable and substitutable.

From the <u>image level</u> we gain our broadest view of the paradigms. It is from this view that we see fundamental beliefs and commitments. They are very general beliefs and commitments that serve to justify the wide range of theories, models, principles and concepts found at the schema level. They become apparent when one considers the collective intents and characteristics of the schema and component levels. Commitment to the image level comes about through repeated exposure to the component and schema levels. The beliefs and commitments of the image level are typically held so strongly that concepts, explanations, arguments or behaviors which cannot be justified on the basis of the image are often considered to be "unrealistic," "ridiculous" or even "superstitious." The image level seldom changes despite changes at the component and schema levels.

The day to day concerns of most engineers and technologists are directed toward the component level; they seek practical approaches in techniques, procedures, example problems, standards, design criteria, etc. A smaller number direct their primary concerns and abilities toward the schema level; they look to such things as theories, models and general principles. The image level tends to be intuitively accepted but seldom studied; epistemological inquiries are not popular within technology.

BEHAVIOR OF TECHNOLOGICAL DISCIPLINARY COMMUNITIES

<u>General</u>. Members of a disciplinary community receive guidance and direction from their paradigms. At the same time, however, the experiences of the members, their disciplinary failures and successes, contribute to the evolution of the paradigms (Toulmin, 1972). If the paradigms suggest that a particular action is reasonable, desirable and economical, then members wish to observe reasonable, desirable and economical results; results which are consistent with paradigm-based expectations. Paradigms are adjusted to improve these results and to respond to changing social

and physical conditions. A technological discipline adjusts to the social-physical world as they see and experience it, a world which they themselves are changing. Thus, technology and the social-physical world adjust to each other (Daniels, 1970)(Layton, 1970)(Burke, 1970). The world is altered by technology while technology is altered by its perception of the world's needs, demands, responses, behavior and properties. I have illustrated this adjustment process as a continual two-way adjustment (gestalt) of technological communities between their paradigms and the social-physical world (Fig. 1). A driving force of this process is a community's desire to obtain more favorable responses for performing discipline directed actions. I will describe four related aspects of this adjustment (evolutionary) process: discipline, innovation, action and observation.

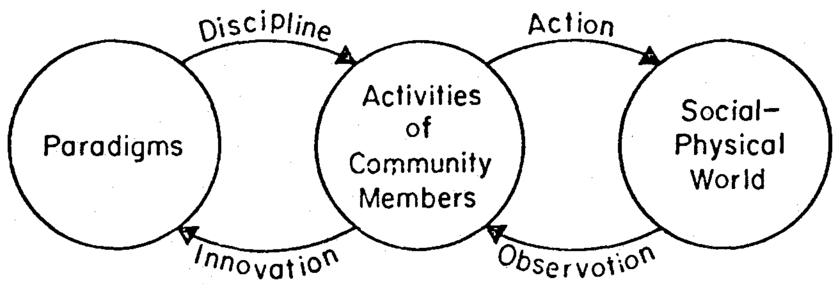

FIGURE 1. TWO WAY ADJUSTMENT (GESTALT) OF COMMUNITY MEMBER ACTIVITIES

Discipline. A primary purpose of discipline is to discourage, prevent and eliminate activities within the community which are incompetent, misguided and inept. The standards for a community's discipline are found in its paradigms. A variety of disciplinary forms can be identified.

Very often, technological activities are performed for people and organizations who are not capable of critical technical review. Technological communities need some way of protecting the quality of such work to protect their professional credibility. Within engineering, a legalistic form of discipline has been directed at the qualifications and capabilities of individuals. Minimum professional standards are legally enforced through a professional registration procedure. To be registered, an individual must be able to demonstrate through education, experience, written tests and interviews that he or she can be expected to do work which measures up to the standards of the community. Review boards are established to make sure registered professionals do not violate this trust.

Some technological activities are performed within institutions which establish their own process of technological review (e.g. large industries, government agencies). Professional registration is often not demanded. Technological discipline is largely maintained through an institutionalized hierarchial (authoritarian, chain of command) system within which advancement is often a major incentive. Institutionalized discipline is often strongly influenced by the goals of the institution which may at times conflict with the disciplinary standards.

The educational experience of individuals prior to their acceptance into a disciplinary community is of major disciplinary importance; it sets standards for disciplined behavior, it provides affirmation for acceptable behavior, and it provides rejection for unacceptable behavior. Students are continually subjected to the authoritative discipline of the community. Grades provide the student with a constant reminder of their ability to meet the standards of the community and if minimum grades are not met, the student will not likely be accepted into the community. The most demanding educational standards are placed upon those who wish to become part of the community's educational process. Moreover, technological educators are often required to continually prove their ability to meet the standards of disciplinary communities by publishing technological work within journals which employ demanding peer review and performing professional work in their specialty.

The largely legalistic and authoritarian forms of discipline found in professional registration and education are not sufficient in themselves to account for technological discipline. These disciplinary forms do not explain how the legalizers and authorities themselves conform to discipline nor do they explain how new standards (paradigms) for discipline evolve in an orderly (disciplined) way. We must look to some disciplinary process which applies to the legalizers and authorities and accommodates changing paradigms. To explain this process, we must recognize that disciplinary communities are social entities. While the majority of engineers and technologists may fall under some legalistic and authoritarian form of technological discipline, these forms of discipline themselves depend upon a more fundamental social process.

In its most basic forms, scientific and technological discipline arise from the human relationships within communities which maintain dialogue, peer respect, recognition and acceptance along with individual responsibility, accountability and pride. Within a socially active disciplinary community, individuals attach much of their personal worth and identity to their work; a rejection of this work is taken as a personal rejection. To have your peers discover a gross error in your work, to feel that your peers believe your work is ridiculous, sloppy, non-rigorous or careless, to lose credibility within your discipline, all of these would be considered as humiliating and devastating personal blows. On the other hand, to have your peers affirm your work, to feel that they recognize, respect and even marvel at your work, to feel that you have become a respected authority within your discipline; all of these are considered to be highly rewarding. These strong social attitudes provide an essential basis for discipline particularly for the legalizers and authorities. The strong social commitment to a community is a commitment to the community's way of doing things; the paradigms. Members gain much of their personal identity through their disciplinary community and thus to disregard the community's paradigms is to discredit oneself. To depart from the accredited paradigms of a community is risky for it increases the risk of being rejected by the community. Thus, discipline is provided by attaching a social risk to activities which depart from the community's standards as expressed in the paradigms.

Professional societies and organizations facilitate and encourage activities of disciplinary communities. Awards and titles are given. Articles are written in professional magazines describing the success and occasionally the failure of projects. Conferences, symposia and meetings are arranged where technological work is openly discussed. Task forces and committees are formed from recognized experts. Memoirs are published. Journals containing technical papers are published. Such papers are reviewed by peers. Further papers or discussions are written which may either ignore, refute or support previous papers. All of these community activities serve to sustain the social importance of informed peer respect and to use this respect to maintain responsible order within the community. Professional societies also seek to place some limitations on the intensity of economic and institutional competition between members in order to maintain this social climate. If competition became so severe that individuals profited by treating other members as cheats, frauds and incompetents, community identity and discipline would decline, and an evolving community knowledge, the paradigms, would become severely retarded.

Without the social discipline of disciplinary communities, technological activities would most likely decline in quality regardless of legal certification procedures or institutional reviews and supervision. Quality professional work requires a disciplinary social climate in which personal identity, pride and responsibility are important. Such a social climate not only discourages poor work but it encourages good work and advancement of the community's capabilities. While obligations to clients and employers are important, such obligations cannot supersede the obligations to the disciplinary communities and their standards if high quality work is to be maintained. Moreover, the support of disciplinary communities may be needed when individuals find that their public responsibilities conflict with the intents of their clients or employers (Turnick, 1975).

Probably the worst technological work is done when two conditions occur. First, the social commitments, reviews and accountabilities within disciplinary communities are circumvented. Motivation may then become dominated by other incentives such as financial success and institutional advancement; disciplinary communities find it difficult to expose incompetence and support quality work. Second, the work performed is such that failures are not obvious. Poor work gets by because it is not likely to be exposed by some obvious failure (like a building collapsing).

Environmental impact studies contain many examples of poor work performed under these two conditions. Too often, studies are conducted merely to meet legal or procedural requirements and often they tend to justify a prior commitment or a vested interest (Clark, 1974). Court cases, agency reviews, public controversy and project delays have provided some incentive for better impact studies (Pearson, 1973) but, too often, the response has been expressed more in the bulk of the report than in its quality. Authorship is often omitted from impact study reports. Who then can be held responsible for the quality of the material in the reports? The process of social discipline has been significantly circumvented by the anonymity of the responsible authors (Ghiselin, 1975). Moreover, post project studies are seldom done and thus, historical accountability is rare. Benefit-cost studies are similarly protected. It would seem that, if an assessment of public concern claims technological credibility, its authors should be technologically accountable beyond their employing institution or client.

Innovation. Technological activities often demand "common sense" adjustments to deal with unique situations and problems. Without common sense adjustments, the application of general paradigms to real world situations would seldom, if ever, be possible. But common sense adjustments to unique situations are not enough. Technological advancement depends upon innovative ways of doing and seeing things that have widespread applicability. The advance of technological paradigms depends upon innovative ideas, concepts, models, theories and approaches which, though often abstract, have lasting widespread influence upon technological activities.

Through such innovations, the paradigms may be adjusted over time to be more compatible with actual observations and experiences. The expansion of water quality models to include inorganic nutrients (e.g. phosphorous, nitrogen) is an example from environmental engineering. Innovations may seek to simplify or resolve inconsistencies within the paradigms; they may enable technological communities to better respond to societal demands or new information, tools and ideas. Innovations may also be needed to resolve problems which involve the interests of several disciplines (Bugliarello, 1972)(Bella and Williamson, 1972). Innovations can be motivated for a variety of reasons: aesthetics, accident, emotions, humanitarian motives, personal values, necessity, need for recognition, interdisciplinary exchanges and, of course, economic incentives.

The alteration of a community's paradigms depends upon a social process in which innovations are discussed, reviewed, criticized and altered within the disciplinary community. If members of the community find that an innovation helps them to be more technologically successful, then, the innovation has an increasing influence upon the community's way of doing things. Innovations which better meet the needs of community members and survive their critical reviews tend to replace older alternatives.

With time, successful innovative concepts, ideas, theories, approaches and procedures become assimilated into the community's paradigms; they become established within the disciplinary literature and educational programs. This social process of disciplined examination, alteration, discussion and critical review and the assimilation of successful innovations into the paradigms is essential to technological advancement; the process serves to filter out incompetent, irrelevant and sloppy work and it provides some assurance that technological paradigms will improve rather than degenerate into a "grab bag" of personal styles, attitudes and biases.

Existing paradigms are used as guides for judging innovations; those innovations which depart most significantly from the paradigms are most likely to be rejected. However, a community may continue to find that without a substantial alteration, the existing paradigms remain deficient in some significant way. If the paradigms have nagging inconsistencies, if they are unable to resolve important problems, if they are becoming fragmented and confusing and if they "don't seem to be going anywhere," then a community may eventually accept innovations which significantly alter the framework of their paradigms (Gutting, 1973). New disciplinary communities may form from several previous communities and old communities may fragment and disappear.

Most innovations noticeably alter a community's paradigms only at the component level and they seldom cause great controversy. Innovations which noticeably alter the paradigms at the schema level are usually more disruptive and controversial; community members may need to update their education to maintain proficiency with the altered paradigms. A significant alteration at the image level, however, is a revolution of historical importance (Kuhn, 1962). Environmental management may require revolutionary changes to cope with expanding technological capabilities (Bella, 1974)(Maruyama, 1973)(Regier et al., 1974).

In a sense, discipline and innovation are in tension with each other (Polanyi, 1964). Discipline needs innovation so that the basis of discipline, the paradigms, can continue to improve and be relevant to current conditions. Discipline, however, tends to constrain innovation. But, innovation needs discipline, for without it, there is no basis for separating the best innovations from incompetent work (Polanyi, 1967). At the same time, however, innovation may depart or even reject the basis of discipline. This tension is necessary if the process of disciplined innovation is to continue. A disciplinary community which accepted nothing new would become irrelevant and outdated. A community which accepted anything would deserve no credibility.

There are numerous examples of technology's capacity to innovatively respond to the needs, demands, schemes, and whims of contemporary society. Without belittling the human significance of these innovations it appears prudent to consider the limitations of technological innovation so that unrealistic expectations do not encourage unwise and even catastrophic social behavior. I will briefly mention two aspects of technological innovation which deserve some thought.

First, some tasks are far more difficult than others. In general, it is far more difficult to foresee the ecological and social consequences of a technological change than it is to produce that change. Thus, with continued technological development, we will most likely face a continuing predicament: our ability to produce changes will increasingly exceed our ability to foresee the consequences of these changes. This predicament necessitates strategies which recognize the limitations of our knowledge and the catastrophic potential of our capabilities (Bella and Overton, 1972)(Solo, 1974).

Second, time is an essential ingredient for disciplined technological innovation. It takes time to dream up new ideas, review, discuss and examine these ideas, and identify the good ideas from those which are poor, inept and even catastrophic. It takes time to gain experience with new ways of doing things and it takes time to recognize the limitations and consequences of these new ways. Technology, like any other human enterprise, can be pushed too fast. When this occurs, poor work gets by and important, but difficult and unprofitable problems (e.g. the decay of cities) tend to be avoided. Statements like, "we were under very tight time constraints" become justifications and excuses for poorly thought out work. Those who take the time to "do it right" find it difficult to compete with those who do not.

Technology can innovatively respond to human needs, but technology itself is a human enterprise with human limitations. Technological advancement can occur, but naive and unreasoned expectations of technological solutions to all our problems can serve as excuses for wasteful and destructive social choices. The metaphorical comment of economist Herman Daly seems appropriate, "while technology will continue to pull rabbits out of hats, it will not pull elephants out of hats - much less an infinite series of even larger elephants (Daly, 1974).

Action. The activities of disciplinary communities within technology involve actions which are directed and controlled by members with the guidance of the paradigms. Such actions may include conducting studies and experiments. They may include the design, construction and operation of physical structures and the manufacture of products. The kinds of actions taken by different technological disciplines are highly varied and they respond to a wide range of perceived societal demands.

A common belief among technologists is that technology deals with actions which originate from society. "Society rightfully sets technology its tasks. We the people, through our role as consumers of industrial output or through our government of elected representatives, determine the goals and put technology to work on them" (Saul, 1974). Such statements are misleading. It is true that technological disciplines respond to economic and political demands but the identification, appropriateness and selection of demands is largely guided by disciplinary paradigms. The paradigms provide guides as to what demands are reasonable, where demands should come from, and how demands should be presented. This does not mean that demands should be in the form of technical instructions. Rather, demands must reasonably conform to the image expressed in the paradigms. A demand such as "I'm lonely, do something about it" would be an inappropriate demand because technological paradigms do not deal with loneliness. This does not mean, however, that the physical structures built through technological action do not have an influence on the loneliness and personal security of individuals who live among and within these structures (Alexander, 1967)(Mumford, 1968)(Milgram, 1970)(Newman, 1973)(Proghansky, 1973). Technological paradigms do provide guides as to what actions should be taken and why certain actions are better than others; they function as filters for selecting demands to respond to and needs to be addressed.

There are other reasons for not considering technology as a passive servant to society. Technologists are often enthusiastic about their work (Florman, 1976); we often promote it and defend it against criticism. Engineers, as an example, are probably known for their ability to hustle support for the kinds of things that they want to do (Ferguson, 1974); indeed, such hustling is typically an economic necessity, even within universities.

Many powerful organizations are closely associated with and often dependent on particular technological actions (e.g. automobile and oil industries, state highway departments, U.S. Army Corps of Engineers, public utilities). Such organizations are often powerful advocates for those technological actions which serve their own interests (Shapiro, 1973)(Solo, 1974)(Melman, 1975) and they exert a significant influence on the development and application of technology (Melman, 1975). Consider engineering education. Large organizations influence engineering education through funding research, providing consulting opportunities for faculty, endowing academic positions, providing jobs for graduates and, in general, by exerting political and economic influence. As a result, there have been many established courses and programs in such areas as industrial engineering, nuclear engineering and highway engineering, yet there have been relatively few courses and programs which might support less consumptive life styles through such technological approaches as solar heating of homes and bicycle transportation.

Through education and job experience, engineers establish professional identities. A societal rejection of those actions which provide ones professional identity is a serious economic, social and psycological threat that most of us would prefer to avoid. It often takes significant commitment and courage to speak out against actions upon which you and your professional colleagues depend. Consequently, some actions which society might have reason to phase out or reduce (e.g. construction of dams, highways, nuclear power plants) appear to be more technologically justified, (i.e. they appear to receive more support from technological experts) because the professional identity, skills, and employment of technologists are closely identified with these activities rather than with less grandiose alternatives (Sullivan, 1976). As an example, consider the tremendous technological and resource commitment to the automobile as a form of day to day transportation when, in an overall sense, bicycle riding and walking might have been a far more reasonable alternative if taken seriously (Illich, 1974).

We also find that people within modern societies often must rely upon technological devices in order to socially survive within a society which has been transformed by technology. As an example, people choose to drive automobiles on a day to day basis because the streets, highways, shopping centers and general sprawl made to accommodate automobiles and the heavy traffic of automobiles make it inconvenient, difficult and even dangerous to walk or ride a bike. Competition also tends to force people and organizations to accept technological devices and approaches in order to competitively survive. In short, the portrayal of contemporary technology as a passive servant to humanity is terribly misleading.

Observation. Technological activities involve observing the behaviors and responses of physical, social and ecological systems. Such observations may be expressed as technical data obtained through an experiment or study. They may include observations of societal costs, requirements and needs through political, social and economic indicators.

Technological actions require observed information: the observed characteristics of a waste are needed to design a treatment facility, and the observed costs of materials, labor and equipment are needed to select a construction method. The success of a technological action depends upon the observed physical, social and economic consequences. The credibility of theories, models and approaches depends upon their dependable agreement with observations. The evolution of paradigms is largely motivated by the desire to have paradigm based expectations agree more closely with observations.

Disciplinary communities within science and technology share a common requirement for valid (objective) observations; they must be reproducible, at least in concept, within the community. This requirement provides the basis for communication and agreement within the community. The requirement does not mean, however, that objective observations are independent of the beliefs and commitments of the observer. Rather, it means that objective observations should essentially depend only upon those beliefs and commitments which are shared by the disciplinary community of the observer. Personal tastes, bias and fancy should not distort disciplined observations. Too often, however, "objective" observations are considered to be determined exclusively by the nature and behavior of the observed systems; they are considered to be independent of the beliefs and commitments of the observer. This notion is misleading! The observer is intimately involved in the observation and the kinds of information selected as valid observations reflect the disciplinary beliefs and commitments of the observer, they reflect the paradigms of the community to which the observer belongs. As an example, a number of experiments (actions) may be conducted and observations recorded as data. This data will reflect the nature of the experiment which was largely guided by the questions and approaches deemed reasonable by the paradigms (Barbour, 1971). The selection and arrangement of the data are also guided by the paradigms. The paradigms provide guidance as to what observations and experiences are relevant. As an example, the natural beauty of a river would not likely be recorded as a technical observation yet the dissolved oxygen content of the water would likely be recorded in an engineering study. "Natural beauty" is not accommodated by the established environmental engineering paradigms but dissolved oxygen content is.

The paradigms of a community act as filters through which disciplined observations are made. That which passes through the filter is accepted for discussion as a reasonable observation. That which does not pass through these filters is considered to be irrelevant, non-rigorous or even ridiculous with respect to the activities of the community.

Paradigms thus give stability and rigor to the activity of a disciplinary community by directing their attention to observations which can be addressed and evaluated by the community in an orderly manner. But these same filters may block out important observations and experiences. A community may be protected from critical observations and difficult questions which cannot be satisfactorily addressed under the guidance of its paradigms (Kuhn, 1962). As an example, let's consider the controversies over nuclear power. I spent some time discussing these controversies with several opponents of nuclear power. This discussion initially involved such issues as reactor safety. I stated that I had no reason to doubt the assurances from nuclear engineers that reactors were reasonably safe. My assurances didn't reduce tensions, they increased them! If I sounded very convincing that reactors were safe (though I'm certainly no expert), a strange thing happened; they became more distressed! I began to realize that issues like reactor safety were real but they were not the primary issues. There are more basic concerns and questions. "Where is our society going?" "What happens to a society which has large amounts of energy available to it?" "Do the beautiful and sensitive aspects of life get sacrificed to 'idols' of production, efficiency, convenience and technological growth?" "What is our convenant with future generations?" (Bellah, 1975) "What are the moral and social implications of such concentrated power?" Make no mistake! Many opponents of nuclear power have not approached these questions lightly. But, the concerns often most important to them seldom get publicly discussed to any depth, particularly among technologists. The technological paradigms don't deal with such concerns; they deal instead with such things as radiation levels, economic efficiencies and reactor safety. Things like sense of community, loneliness, feelings of insecurity, closeness to nature, and covenants with future generations aren't accommodated by technological paradigms, they don't pass through the technological filters, and so they tend to get dismissed as personal, emotional, impractical or unrealistic. Discussions then shift to topics like reactor safety. But the conflicts do not become resolved because concerns important to some people are avoided or discounted as irrational or emotional (a term used with a negative connotation). The technological paradigms have tended to protect technological communities from a number of controversial issues by filtering out concerns which are difficult if not impossible to address through the technological paradigms.

TECHNOLOGY AS A SET OF COMMITMENTS

The preceding sections of this paper have discussed disciplinary communities and their paradigms; and the behavior of disciplinary communities within technology. In this section, I reason that technological communities share a number of important commitments which distinguish them from other disciplinary communities. Disciplined technology can be considered as a family of disciplinary communities with common basic commitments. Our task will be to describe these common commitments. Technologists, of course, respond to rational, moral and social beliefs, commitments, and traditions not unique to technology (Susskind, 1973). However, our discussion will focus upon those commitments which characterize technological discipline.

A Technological Image. We have discussed how paradigms can be viewed from different levels of resolution; that is, from different degrees of detail and perspective. We employed three levels of paradigm views: The component level, the schema level and the image level. From schema and component level views, the paradigms of different technological communities often appear quite dissimilar. As an example, the techniques, procedures, examples, models and theories of sanitary engineers are not the same as those of electrical engineers; each would find it difficult to switch jobs. Different technological paradigms, however, tend to merge at the image level. That is, from an image level view, essential similarities can be identified among the different technological paradigms. We will speak of these image level similarities as forming a technological image, an image which is shared by technological communities. This technological image acts as a general filter through which the world and activities within the world are viewed. Explanations and activities which do not pass through this filter are not technological. Problems and solutions which are not expressed in a manner compatible to the technological image are not technological.

I have attempted to gain some understanding of the technological image by first asking myself "what did I really get by working all of those problems as an engineering student?" "What common characteristics did those problems encourage?" Neatness and punctuality in turning in assignments were of course encouraged, but many college courses which are not technological do this. What set of commitments and beliefs did engineering courses encourage that courses in, say, music, religion and art did not? Could we find these same commitments and beliefs encouraged for good technological work in general. What characteristics normally apply to disciplined technological activities but do not normally apply to non-technological disciplined activities?

I believe that the technological image can be best imagined as a set of commitments. I have listed seven such commitments in Table 1. Technological disciplines are those which rely heavily upon these commitments. The commitments say to technological communities, "these are the behaviors which this community has found to be desirable and important; activities within this community should be guided and justified on the basis of these commitments." These commitments serve a primary function of justifying technological activities. As an example, in my research, I may make a discovery through guesses, intuition, indirect means or even by accident. But when I present the results to my technological discipline, I attempt to justify then on the basis of the technological commitments. Thus in my technical paper I don't say things like "this idea came to me as I was watching my sons play in a mud puddle," even though that may be true. Instead I justify my idea by showing its usefulness and validity in an analytical and objective way, preferably with quantitative data properly presented in tables, graphs and equations.

The models, concepts and theories found at the schema level of technological paradigms and the procedures, techniques and examples found at the component level of technological paradigms are deemed reasonable because they enable technologists to fulfill the commitments of Table 1. As an example, techniques to measure dissolved oxygen in water are part of the environmental engineering paradigms because they enable objective (commitment 5) and quantitative measures (commitment 3) of conditions within a river at a point in time (commitment 7). The impact of low dissolved oxygen, dead fish, can be observed and documented (commitment 6). Dissolved oxygen is an important part of an explanatory model of rivers (commitment 2) from which plans and designs can be developed (commitment 4) so that sewage treatment plants can be constructed and operated to reduce adverse impacts (commitment 1). The resulting reduction or elimination of impacts can be objectively observed (commitment 3, 5 and 6).

These image level commitments are not precise rules to be followed! They do not form an exact guide! Instead, the commitments must be balanced, often against each other. They provide guidance but the balancing of them for particular situations requires a degree of personal judgment. As an example, commitment 1 of Table 1 encourages useful and economically efficient activities. Commitment 3 emphasizes the importance of precise measurements. It takes time, effort and money to get precise measurements; this could result in costs so high as to make the activity uneconomical and useless. On the other hand, imprecise work can lead to dubious, sloppy and unprofessional results. Time and economic constraints are often practical realities but they also can serve as excuses for shoddy work. A practical balance between economic efficiency and usefulness on the one hand and exactness, rigor and precision on the other is needed.

I suggest that the contemporary use of the work "technology" should describe an association with the commitments shown in Table 1. A technological discipline, as we have examined in this paper, is one which holds these commitments as fundamental. But these technological commitments are not limited to disciplinary communities. A technological society is one in which these commitments have a dominant influence on its behavior, attitudes, decisions and public debates. A technological device is one which can be reasonably justified on the basis of these commitments. A technological outlook is one which is highly influenced by these commitments. When we speak of transferring our technology to another society we mean not only giving them the physical objects designed and deemed reasonable by these commitments (e.g. dams, roads, cars, factories, tractors, planes, etc.) but we also mean giving them a way of thinking, a way of identifying problems and pursuing solutions (Newell (1974) provides an example of the technological commitments applied to baseball!).

<u>Non-Technological Statements</u>. Activities which do not reasonably conform to the commitments in Table 1 are not technological activities. Activities which are technological activities should not treat them lightly. To illustrate the influence of these technological commitments, I have listed in Table 2 a number of non-technological statements. I believe that it would be quite unusual to hear such statements within a serious technological discussion. I doubt that these statements would describe the basis of an engineering study. Any student who relied upon such statements would not likely pass a qualifying exam for an advanced

engineering degree. In the second column of Table 2, I have listed the commitments from Table 1 which the statement violates. Violations may be either direct or implied; there may be more violations implied than are listed. In the third column, I have listed a type of person who might find the statement to be acceptable and reasonable. Thus, Table 2 seeks to illustrate that statements which are not technologically acceptable, may be acceptable on a non-technological basis. Try this simple exercise. Read a statement or quotation from Table 2, and then immediately compare it to the appropriate commitments in Table 1 (identified in Column 2, Table 2). I believe that you will notice the contrast.

Implications. The statements in Table 1 say, "These are the behaviors which we have found to be reliable and useful; activities within the community will be judged on the basis of these tested commitments." It is important to note that these statements do not directly state "this is how the real world is." Such statements are found at the schema level but the justifications of these schema level statements rely upon the behavioral commitments at the image level. We make a technological statement concerning the nature of the real world because making such a statement is compatible to the commitments found at the image level. As an example, we say that f=ma describes real world behavior, because we've analyzed systems (commitment 2) and found this relationship to be compatible to objective observations (commitment 5 and 6) involving precise measurements (commitment 3 and 7); it's also a highly useful relationship (commitment 1) which enables precise plans and designs (commitement 4).

Technology is based upon commitments which we (technological people) have chosen to direct our own behavior. These foundations, the basic commitments, are not "the facts given to us by nature." True, we have found these commitments to be useful and reliable for a wide range of actual applications. But, our technological understanding of the word useful and reliable presume these commitments. If, as an example, we hadn't already accepted these commitments, or something like them, Newton's second law of motion (f=ma) would make little sense to us. These basic commitments upon which technology rests, its unique foundations do not say "this is the way the world really is;" instead they say "our own activities should be guided and justified in this way," This distinction is important!

The technological commitments of Table 1 do encourage (suggest, promote, imply) a particular concept (image, frame, picture) of reality. This concept of the real world is that of classical (nineteenth century) physics; it is a world of objects, quantities, forces, determinism, causality, space and impersonal time which can and should be objectively analyzed and altered for useful purposes. It is the concept of reality most clearly expressed in applied mechanics. It has been a rigid conceptual frame which has dominated western consciousness (Northrop, 1959). Physicist Werner Heisenberg describes this rigid frame in the following way.

"This frame was supported by the fundamental concepts of classical physics, space, time, matter and causality; the concept of reality applied to the things or events that we could perceive by our senses or that could be observed by means of the refined tools that technical science has provided. Matter was the primary reality. The progress of science was pictured as a crusade of conquest into the material world. Utility was the watchword of the time" (Heisenberg, 1962).

This classical frame has been broadly accepted as reality, "the way it really is." Modern physics, however, no longer accepts this frame as reality itself. Heisenberg (1962) states, "one may say that the most important change brought about by its (modern physic's) results consist in the dissolution of this rigid frame of concepts of the nineteenth century." The assumption that the paradigms actually describe reality as it "really is" has been challenged. Ian Barbour (1971) expresses this in the following way, "The nineteenth century assumption that scientific theories are *literal* descriptions of nature as it is in itself can no longer be accepted in physics" (italics are Barbour's). (Also see Shilling, 1973).

We do not have to rely upon modern physics to tell us that the image of reality implied by the commitments of Table 1 is too restrictive. We can think of our own experiences, particularly those which we find to be most meaningful. Think what would happen to a tender relationship between parent and child if it was constrained by the commitments of Table 1. What does a sunset look like when viewed through the technological image? How could we appreciate or justify a great symphony merely through the technological commitments?

I am not arguing that technology (or classical physics) is wrong. We can hardly deny that it works for many activities (e.g. building bridges and sewage treatment plants or landing a spacecraft on Mars). We need not deny that it works! We can justify the statement that technological understanding works for many kinds of activities; it is on this basis that a technological image can be defended.

By recognizing that the basic technological commitments (image level commitments) are a common basis for guiding and justifying our own activities, several things happen. First, we technologists are more strongly forced to accept the responsibilities for our own behavior. We can't simply say, "well, I'm sorry, that's the way the real world is and there's nothing that I can do about it." Second, we are forced to realize that reality may be far more than our image implies, after all, why should reality be confined to our own behavioral commitments.

Reality is more than that which is defined under the technological commitments and much more is expected of human behavior than that deemed reasonable through the technological commitments. We must be concerned, not just with the misapplications of technology, but with its tendency to narrow human conscienceness, to constrain the scope of acceptable human concerns and impose its own exclusive standards of success. (Ellul, 1963, 1964)(Mesthene, 1971)(Solo, 1974)(Albrecht, 1975).

BEYOND TECHNOLOGY

In this final section I will briefly suggest that technology is based upon an ultimate concern which transcends its image level commitments. Moreover, I believe that technology, science and even religion are based on similar ultimate concerns. I will also reason that technology, science and religion share a common fault: each of them can lose sight of their ultimate concern by dogmatically treating their lesser commitments as ultimates. This section will be brief, only crudely touching upon some concerns which demand far more than I am now capable of giving.

The Concern for Quality. Within technology, science and religion we encounter what might be called ultimate concern (Tillich, 1959). We could describe this concern in many different ways and I suspect that all such descriptions would be inadequate. For our present discussion, let us employ the word Quality (Pirsig, 1974). We can say, in an admittedly inadequate way, that technology ultimately depends upon a quest for Quality in its fullest sense. I use the word Quality herein not as something like a performance standard, but rather as a word symbolizing ultimate meaning, goodness and much more. We will use the word Quality to symbolize that which provides an urging, a motivation and a confirmation for the best of human activities. We will say that the quest for Quality, responding to its urgings and participating in its existence; these provide meaning, hope, elegance and purpose to human enterprises.

We know of this Quality by participating in it by experiencing it within paradigms guided activities and without. Rules, explanations and guidelines may point toward Quality, but, ultimately, you either experience it or you don't. I cannot provide a definition of this Quality; it is a symbolic word pointing to something beyond words. We can only talk of our own experiences and, in so doing, we may be able to say to each other, "yes, I know what you mean." As an illustration there seems to be a limit beyond which a teacher cannot further explain a problem or concept. Beyond this limit, the student must experience somthing which the teacher alone cannot directly give. The student must experience a glimpse of a Quality which leads him or her to say "AHA, now I really understand what you are saying." Without the AHA experience (Korstler, 1971) the efforts of the teacher are futile. It's these glimpses of Quality, the AHA experiences, that make the difference between understanding and mere mimicry, between education and indoctrination (programming), between maturing and getting old, between human wisdom and computer "thinking."

The pursuit of Quality involves a moral commitment. To betray the urging of Quality, to disregard the better for the lesser, to ignore that which you feel with your whole being to be good, to close your mind to better ways, all of these behaviors stand condemned by science, religion and technology. If each technologist approached his or her workday with the intent of doing only that which is personally safe and profitable, all kinds of deceptions would be possible and eventually, there would be neither standards by which deception could be detected nor a community which cared about such standards. Consider the many opportunities available to manipulate and even falsify data and not get caught. What do you think would happen to technology if technological communities didn't care? The commitments of Table 1 are worthless unless there is a transcending moral commitment to seek that which we have called Quality; not quality by some lesser standards, but Quality as you know it with your whole being. One is expected to do more than just follow rules. One is expected to apply rules with a personal judgment which is motivated by the quest for Quality. As an example, good teachers become extremely frustrated by students who merely memorize. Such students seem unable or unwilling to seek Quality beyond any stated rules or facts, they simply "don't get it." They want to be told exactly what to do, but that can't be done! You simply can't give students a set of rules and equations that will make them good engineers! They must seek something beyond the rules and equations, that essential something I have called Quality.

The Demonic. The word "demonic," as theologian Paul Tillich used this word (Tillich, 1967), (Benne and Hefner, 1974), describes a process whereby something basically good is overextended and treated as an ultimate. Benne and Hefner (1974) describe the word demonic this way: "The demonic is the power that takes a manifestation of goodness and pushes it beyond its capabilities and its finiteness, so that the manifestation of goodness becomes transmuted into a vehicle of evil and destruction. To say that something is demonic is to acknowledge that it is basically good but its goodness has been nullified by its own pretensions to be more than a vehicle for goodness, to become the Good." Technology, science and religion seem to continually struggle with this demonic. Technological, scientific and religious paradigms can be reasonably accepted as ways of obtaining the good and worthy. But, we may feel so successful in their use, that we lose sight of the fact that they are vehicles to goodness, to Quality. If we are not careful, our vehicle to Quality becomes elevated to a position where it defines Quality. It then becomes a constraint on and a substitute for Quality. It becomes demonic.

Technology certainly has the capacity to help us attain worthy goals (Quality motivated goals) but technology becomes demonic (in the Tillich sense) when we insist that any worthy goal must be defined in technological terms. Similarly, economics can be a useful tool for obtaining worthy goals but it becomes demonic when we insist that the goodness and worth of anything must be expressed in economic terms. The market system has many desirable properties as a process through which a society can make good and worthy choices. But the market system becomes demonic when we insist that it defines the good and the worthy by its own distributive mechanisms. In these examples and others, a vehicle or means to Quality becomes demonic when it tends to consider itself as ultimate; when it insists that Quality be defined (constrained) under its own commitments and rules.

The avoidance of the demonic involves taking paradigms seriously but not ultimately. I suspect this is why the two words faith and humility have been so important in human affairs. Faith in paradigms is necessary to provide guidance and standards for behavior. But faith must be tempered with an individual and corporate humility which prevents these same paradigms from becoming demonic. Arrogance is an indicator of the demonic.

The success of technology has resulted in a societal faith in the "technological fix," the belief that essentially all really important problems can be solved by technology. But this faith has not been tempered with a humility. This lack of humility is evident in the relationships between technological and non-technological cultures. Even in their desire to help, technological societies have tended to be arrogant. Non-technological cultures are expected to learn from technological cultures but the reverse learning has seldom been taken seriously by the latter. In my own experience with well intentioned programs to assist the American Indian, technological assistance was provided in the form of water and sewage facilities, transportation and housing projects, education and medical care. But these programs were not balanced by an attitude which said, "What can we learn from these cultures and what can our two cultures learn together which neither could separately learn?" (Shanks, 1974). Thus, such acts of giving and assisting, while motivated by good intentions, reflected a technological arrogance which may be demonic and work to the detriment of both cultures.

A Closure. If we seriously wish to use technology for worthy purposes, we must acknowledge that the Quality which bestows worthiness upon a purpose transcends technology itself. The concern for Quality transcends the lesser technological commitments (Tabel 1). These technological commitments are, no doubt, useful for many worthy purposes but they cannot be the guides to their own limitations; they may become demonic and exclude the most significant questions.

How then can we seek Quality beyond technological commitments so that technology itself can be evaluated and guided? I suspect that the most significant human experiences, personal and communal, reveal common beliefs and behaviors which may be of use. We can look to the most moving experiences of our own lives, the most revered experiences of sensitive communities and the human stories whose enduring value has given them the title of sacred. In these we find gentle beliefs which somehow seem to survive a history of deceptive misuse, arrogant ambition, and demonic transformation. It is to these gentle beliefs that the awesome power of modern technology must submit: a sense of wonder, awe and humility; an acceptance of others who are different and a willingness to learn from them; a sensitivity and concern for ourselves, and others and our environment; a willingness to participate in honest dialogue in its fullest sense (Buber, 1970); a nurturing honesty which enables us to learn from our mistakes, faults and inadequacies (Benne and Hefner, 1974); a responsive concern for the misuse of power by ourselves and others (Bella, 1977); a hope which, at times, may even be irrational; a courage to speak and act for what we feel to be right with a humility that recognizes that we may be wrong; and a willingness to take time so that the gentle things which provide grace, meaning and purpose to life are not consumed by the "obvious."

TABLE 1 TECHNOLOGICAL COMMITMENTS

1. One should seek to alter and control the physical world for useful purposes. This is done by utilizing human and natural resources to plan, design, construct, manufacture and modify structures, machines, devices and products in an economically efficient manner. Benefits (to be maximized) and costs (to be minimized) should usually be measured in economic terms.

2. The way to unerstand a complex system or problem is to break it down into its basic parts. The behavior and properties of the parts should be methodically examined. The entire system or problem may be then understood by integrating the behavior and properties of the parts in a rigorous manner[a].

3. Explanations, descriptions, goals, problems and solutions should be defined in the unambiguous manner. One should strive to employ quantitative measurements which can specifically relate real world properties and behaviors to unambiguous standards and scales. Imprecise, vague, hazy, indefinite and fuzzy approaches are nonrigorous and should be avoided.

4. Plans, specifications and procedures should be carefully defined prior to the initiation of a project so that: the project can be done in an orderly and efficient manner, the specified end product can be attained and the occurrence of unanticipated changes, surprises and disorders can be minimized. Precise maps, drawings, charts, schedules, performance criteria and written specifications are used for this purpose. Factors of safety should be applied to account for limited information so as to minimize the risk of wasteful and destructive departures from the original plan or design.

5. One must strive to deal in facts without distortion from one's personal feelings, emotions or prejudice. One must deal with real events and phenomena as external rather than as affected by one's personal position, reflections or feelings; that is, explanations, descriptions, problems and solutions should be approached objectively. They should not be approached subjectively.

6. The real world is known through the five senses: sight, touch, hearing, taste and smell. Sight and touch are the most reliable while smell and taste are the least reliable. Theories, laws, explanations and concepts must agree with reliable sense based observations of real world behavior. Observations should preferably be expressed in unambiguous visual forms (graphs, equations, instrument readings, diagrams, statistical data, tables, precise written statements, etc.).

7. Time is to be considered as a continual sequence of instants representable by numbers. The passage of the real world through time should be expressed as uniform, constant, uninfluenced by events and entirely impersonal. It is meaningful to speak of reality at a point in time. Time should be quantitatively measured by the succession of impersonal events (e.g. the rotation of the earth, the mechanical movement of a clock, the decay of a radioactive isotope, etc.).

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[a] Systems and parts (subsystems) may be defined at different levels of resolution. As an example, a bridge may be considered as a part in a transportation system or a bridge may be considered as a system in which a beam is a part.

TABLE 2 STATEMENTS AND QUOTATIONS WHICH ARE NOT COMPATABLE WITH THE TECHNOLOGICAL COMMITMENTS

Statement or Quotation	Violated Commitment[a]	Persons for which Statement or Quotation is Reasonable
I know that it's not practical but sometimes you just have to rely upon faith and eternal grace.	1,2,3,4,5,6,7	Minister, Priest
My writing is beautifully subtle.	3,5	Poet
It's a beautiful devise; of course, it doesn't do anything.	1	Modern Artist
I'm going to have a baby!!	4,5	Expectant Mother
"the Pauli Exclusion Principle--a law concerning the total atom which cannot conceivably be derived from laws concerning individual electrons"	2	Physicist-Philosopher-Theologian, Ian Barbour (1971, p. 295).
"Law is only fulfilled if it is fulfilled with joy"	5,6	Theologian, Paul Tillich commenting on the words of Jesus, Paul and Luther (1959, p. 142).
"Future and Past are separated by a finite time interval the length of which depends on the distance from the observer."	7	Modern Physicist, Werner Heisenberg commenting on relativity (1962, p. 115).
"The surest mark of bad planning...the planner is tempted to set up a single standard of success, that of quantitative use, and overlook the need for variety and choice."	1,3	Historian-Sociologist, Lewis Mumford commenting on city and transportation planning (1968, p. 87).
"Atoms consist of empty space and probability waves."	6,7	Physicist-Philosopher-Theologian, Ian Barbour commenting on Quantum Theory (1971, p. 287).
"You do not know how to point to or define the meaning, you lack any formula or image for it and yet is is more certain for you than the sensations of your senses."	5,6	Theologian; Martin Buber (1970, p. 159).
"We are conditioned to believe that the purpose of knowledge is to utilize the world. We forget that the purpose of knowledge is to celebrate God."	1	Theologian-Philosopher, Abraham Heschel (1965, p. 117).
"It is only with the heart that one can see rightly; what is essential is invisable to the eye."	6	Antoine de Saint Exupery, author of The Little Prince (1943, p. 87).
"If you wish to follow-the poets calling-you've got to come out of the measurable doing universe into the immeasurable house of being."	1,3	poet, e. e. cummings (1965, p. 3)
"The wise have one wish left: to know the Whole, the Absolute The foolish lose themselves in fragments and ignore the root."	2	Seventeenth Century Poet, Angelus Silesius, (Frank, 1976, p. 86)

[a] Numbers in this column refer to technological commitments from Table 1.

REFERENCES

Albrecht, P., "Technology: New Directions in Social Ethics," Christianity and Crisis, Vol. 35, No. 7, April 28, 1975, pp. 92-98.

Alexander, C., "The City as a Mechanism for Sustaining Human Contact," Environment and Man, Commissioned and edited by Ewald, W.R., Indiana University Press, Bloomington and London, 1967, pp. 60-109.

Barbour, I.G., Issues in Science and Religion, Harper and Row, New York, 1971.

Beer, F.P. and Johnston, E.R., "Vector Mechanics for Engineers," McGraw-Hill Book Company, New York, 1962.

Bella, D.A. and Overton, W. Scott, "Environmental Planning and Ecological Possibilities," Journal of the Sanitary Engineering Division, ASCE, Vol. 98, No. SA3, June 1973, pp. 579-592.

Bella, D.A., "Fundamentals of Comprehensive Environmental Planning," Engineering Issues-Journal of Professional Activities, ASCE, Vol. 100, No. E11, January 1974, pp. 17-36.

Bella, D.A. and Williamson, K.J., "Conflicts of Interdisciplinary Research." J. Environmental Systems, Vol. 6 (2), 1976-77, pp. 105-124.

Bellah, R., "The Broken Covenant," The Seabury Press, New York, 1975.

Benne, R. and Hefner, P., "Defining America," Fortress Press, Philadelphia, 1974.

Buber, M., I and Thou, translation by Walter Kaufmann, Charles Scriber's Sons, New York, 1970.

Bugliarello, G., "Technological Innovation and Hydraulic Engineering," Journal of the Hydraulics Division, ASCE, Vol. 98, No. HY5, May 1972, pp. 751-764.

Burke, J.G., "Comment: The Complex Nature of Explanations in the Historiography of Technology," Technology and Culture, Vol. 11, No. 1, January 1970, pp. 22-26.

Clark, I.D., "Expert Advice in the Controversy about the Supersonic Transport in the United States," Minerva, Vol. XII, No. 4, October 1974, pp. 416-432.

cummings, e.e., e.e. cummings - a selection of poems, see introduction by Gregory, H., Harcourt, Brace and World, Inc., New York, 1965.

Daly, H.E., "The Economics of the Steady State," The American Economic Review, Vol. LXIV, No. 2, May, 1974, pp. 15-21.

Daniels, G.H., "The Big Questions in the History of American Technology," Technology and Culture, Vol. 11, No. 1, January 1970, pp. 1-21.

Ellul, J., "The Technological Society," Vintage Books, New York, 1964.

Ellul, J., "The Technological Order," from the Technological Order, ed. Carl F. Stover, Wayne State University Press, Detroit, 1963.

Exupéry, A. de Saint, The Little Prince, Harcourt, Brace and World, Inc., New Your, 1943.

Ferguson, E.S., "Toward a Discipline of the History of Technology," Technology and Culture, Vol. 15, No. 1, January 1974, pp. 13-30.

Florman, S.C., The Existential Pleasures of Engineering, St. Martin's Press, New York, 1976.

Frank, F., "Anglelus Silesius: Western Zen Poet," Parabola, Vol. 1, Issue 3, Spring, 1976, pp. 82-95.

Ghiselin, J., "Commentary-Making the Environmental Report A contribution to Knowledge," Ecology, Vol. 56, No. 2, Early Spring, 1975, pp. 263-264.

Gutting, G., "Conceptual Structures and Scientific Change," Studies in History and Philosophy of Science, Vol. 4, No. 3, November 1973, pp. 209-230.

Hagstron, W.O., The Scientific Community, Southern Illinois University Press, Carbondale and Edwardsville, 1965.

Heschel, A.J., Who is Man, Stanford University Press, Stanford, California, 1965.

Heisenberg, W., Physics and Philosophy, Harper and Row, New York, 1962.

Illich, I., Energy and Equity, Harper and Row, New York, 1974.

Koestler, A., The Ghost in the Machine, Henry Regnery Co., Chicago, 1971.

Kuhn, T.S., The Structure of Scientific Revolutions, The University of Chicago Press, Chicago, 1962.

Layton, E., "Comment: The Interaction of Technology and Society," Technology and Culture, Vol. 11, No. 1, January 1970, pp. 27-31.

Layton, E.T., "Technology as Knowledge," Technology and Culture, Vol. 15, No. 1, January 1974, pp. 31-41.

Maruyama, M., "Human Futuristics and Urban Planning," American Institute of Planners-Journal, September 1973, pp. 346-357.

Melman, S., "The Impact of Economics on Technology," Journal of Economic Issues, Vol. IX, No. 1, March, 1975, pp. 59-72.

Mesthene, E.G., "Technology and Humanistic Values," Science Journal, October 1969, also republished in Technology, Human Values and Leisure, edited by Kaplan, M. and Bosserman, P., Abingdon Press, Nashville, 1971.

Milgram, S., "The Experience of Living in Cities," Science, Vol. 167, March 13, 1970, pp. 1461-68.

Mumford, L., The Urban Prospect, Harcourt, Brace & World, Inc., New York, 1968.

Newell, K.M., "Decision Process of Baseball Batters," Human Factors, Vol. 16, No. 5, 1974, pp. 520-527.

Newman, O., Defensable Space, Collier Books, New York, 1973.

Northrop, F.S.C., The Logic of the Sciences and the Humanities, World Publishing, New York, 1959.

Pearson, J.R., "Impact Statements-Present and Potential," Engineering Issues, ASCE, Vol. 99, No. , October 1973, p. 4.

Pirsig, R.M., Zen and the Art of Motorcycle Maintenance, William Morrow and Company, Inc., New York, 1974.

Polanyi, M., Personal Knowledge, Harper and Row, New York, 1964.

Polanyi, M., Science, Faith and Society, The University of Chicago Press, Chicago and London, 1964.

Polanyi, M., "The Growth of Science in Society," Minerva, Vol V, No. 4, Summer 1967, pp. 531-545.

Proshansky, H.M., "The Environmental Crisis in Human Dignity," Journal of Social Issues Vol. 29, No. 4, 1973, pp. 1-20.

Regier, H.A., Bishop, P.L. and Rapport, D.J., "Planned Transdisciplinary Approaches: Renewable Resources and the Natural Environment, Particularly Fisheries," Journal Fisheries Board of Canada, Vol. 31, No. 10, 1974, pp. 1683-1703.

Saul, G.W., "On Technology and Us," Bechtel Briefs, Vol. 29, No. 2, February 1974, p. 3.

Schilling, H.K., "A Human Enterprise," Science, Vol. 127, June 6, 1958, pp. 1324-1327.

Schilling, H.K., The New Consciousness in Science and Religion, United Church Press, Philadelphia, 1973.

Shanks, B.D., "The American Indian and Missouri River Water Developments," Water Resources Bulletin, American Water Resources Association, Vol. 10, No. 3, June 1974, pp. 573-579.

Shapiro, D.L., "Can Public Investment have a Positive Rate of Return," Journal of Political Economy, Vol. 81, No. 2, Part I, March/April, 1973, pp. 401-413.

Solo, R., "Problems of Modern Technology," Journal of Economic Issues, Vol. VIII, No. 4, December 1974, pp. 859-876.

Streeter, H.W. and Phelps, E.B., "A Study of the Pollution and Natural Purification of the Ohio River," U.S. Public Health Service, Public Health Bull. No. 146, 75, 1925.

Sullivan, J.B., "A Public Interest Laundry List for Technology Assessment: Two Dozen Eternal Truths about People and Technology," Technological Forecasting and Social Change, Vol. 8, No. 4, 1976, pp. 439-440.

Susskind, C., Understanding Technology, The Johns Hopkins University Press, Baltimore and London, 1973.

Tillich, P., "Theology of Culture," Oxford University Press, London, 1959.

Tillich, P., "Systematic Technology," Vol. 3, University of Chicago Press, Chicago, 1967, pp. 102-106.

Turnick, T.L., "Public Versus Client Interests-An Ethical Dilemma for the Engineer," Engineering Issues, ASCE, Vol. 101, No. E11, January 1975, pp. 61-65.

Toulmin, S., Human Understanding, Princeton University Press, Princeton, New Jersey, 1972.