AN ABSTRACT OF THE THESIS OF

Saher A. Bishara for the degree of Master of Science in Industrial Engineering presented on March 12, 2002. Title: The Effectiveness of Cockpit Task Management Training on Task Prioritization Performance in Simulated Flight.

Abstract approved: __Redacted for privacy_____

Kenneth H. Funk II

The cockpit is an environment in which many important tasks simultaneously compete for pilot attention. Cockpit Task Management (CTM) is the process by which pilots selectively attend to flight tasks in such a way as to safely and effectively complete a flight. CTM has been categorized as a mental function that is inherently well understood by pilots and almost always performed satisfactorily (for example, through the trained Aviate, Navigate, Communicate, Manage Systems hierarchy). However, there are documented instances, such as incident and accident reports, where tasks were not managed properly, resulting in an aircraft mishap. CTM involves the prioritization of flight tasks based on their importance to flight safety, urgency, and how well the tasks are actually being performed. Task prioritization errors occur when pilots do not give attention to a higher priority task (i.e., one more important to flight safety, one that is more urgent, or one that is currently not being performed satisfactorily) by attending to a lower priority task (i.e., one less critical to flight safety, one less urgent, or one that is already being performed well and is not in need of immediate attention).

The goal of this thesis was to develop a CTM training program to aid pilots' task prioritization performance. Microsoft Flight Simulator 2000 with yoke,

throttle, and rudder pedals, was used to assess pilot task prioritization performance before and after training. Three experimental groups were used: a control group (no training), descriptive group (CTM lecture training), and prescriptive group (CTM lecture training plus mnemonic procedure) to test the effectiveness of CTM training on task prioritization in simulated flight. Results showed that the prescriptive group improved in task prioritization performance in the post-training flight. Additionally, results showed that the descriptive and prescriptive groups both improved in memory recall (a second dependent measure). It was concluded that CTM training is effective on task prioritization performance.

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The Effectiveness of Cockpit Task Management Training on Task Prioritization Performance in Simulated Flight

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented March 12, 2002

Commencement June 2002

Master of Science thesis of Saher A. Bishara presented on March 12, 2002

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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ACKNOWLEDGEMENT

This work was made possible by the National Aeronautics and Space Administration (NASA), Ames Research Center, supported under grant NAG 2-1287. With special thanks to Dr. Key Dismukes, our technical monitor. He has been very supportive of our work, both technically and financially.

I would like to acknowledge and thank myself for sustaining the drive and determination to complete this thesis. It's been a long path since my decision, in 1993, to pursue human factors research.

My thanks to God.

I would like to extend my appreciation to Dr. Kenneth Funk for giving me the opportunity to pursue my long-held goal of working in aviation human factors. I am genuinely grateful for his kindness, his support, and his advice throughout my time at Oregon State University. His professionalism will serve as a model to me.

I would like to thank my committee for their time and advice. Dr. Jeffrey Woldstad and Dr. Lewis Semprini both offered invaluable commentary. My special thanks to Dr. Doug Derryberry, my minor advisor, for his generous time, kindness, and mental support throughout the duration of this project.

My gratitude goes out to Dr. Curt Braun and faculty at the University of Idaho for giving me the opportunity, and encouragement to pursue graduate work.

This project would not have been possible without the pilot participants, and I extend my deepest gratitude to them.

My friends from India, Taiwan, the Middle East, Japan, Indonesia, Haiti, Europe, South America, China, Africa, Persia, and the United States created an extended family for me through their friendship, support, and food!

I would like to sincerely thank my family: my father and mother, Anis and Salma Bishara, and my three older brothers, Tawfiq, Elias, and Edwar, for making all this possible.

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The Effectiveness of Cockpit Task Management Training on Task Prioritization Performance in Simulated Flight

CHAPTER 1: INTRODUCTION

It was a clear and smooth night for flying on December 29th, 1972, with great weather and unlimited visibility on the east coast. Flight 401 was approaching Miami International Airport from JFK International Airport. On board the commercial jet were 163 passengers, 10 flight attendants, three crewmembers, and one maintenance supervisor. Among the crewmembers occupying the cockpit were the captain (with 30,000 hours of flight time), First Offier (with 6,000 hours), Flight Engineer (FE) (with 15,700 FE hours), and the Senior Maintenance Supervisor in the jump seat.

Approaching runway 9-left into Miami, the crew lowered the landing gear. However, only the green lights (indicating landing gear down) for the left and right main gears were illuminated; the nose gear light did not illuminate. It was possible that the nose gear was safely down and locked and that the light bulbs had failed, although the captain did not make this assumption without investigation of the malfunction. The First Officer (FO) was given two new bulbs to replace the old ones, but could not reinsert the fixture back into place. Therefore the lights did not illuminate because the fixture was not reinserted on the landing gear light panel. At that point, the captain (Capt) decided to abandon the approach and landing until the problem was fixed. The Capt reported their situation to the controller, and intended to correct the situation before making a landing.

The controllers instructed Flight 401 to climb and maintain 2,000 feet, and flight vectors would be given for a landing to runway 9-left. The auto-pilot was engaged by the FO and operating in the command mode. During flight vectoring,

the flight crew became engrossed in resolving the malfunction, and the plane descended to 1,900 feet. The continuing conversation in the cockpit concerned the crew's inability to get the bulb back in place. The aircraft at this point had an undetected 90 feet per minute rate of descent, and then increased to 255 feet undetected. The FO, trying to resolve the bulb malfunction, and crewmembers assisting him, still could not get the malfunction resolved. While the crewmembers discussed possible resolutions, the altitude alert sounded, signaling an altitude deviation of 300 feet or more from desired altitude. Because no one heard the signal, the crew did not react to the altitude deviation. Instead they proceeded in resolving the malfunction through different methods of visual identification to determine if the nose landing gear was down. The aircraft progressed to an undetected rate of descent of 1,070 feet per minute. The FE and maintenance supervisor checked the electronics equipment compartment and visually confirmed that the nose gear was down and locked.

The Capt then responded to the controller's concern, and reported that they were ready to turn around and come back for landing. The controller ignored his falsely assumed radar readings of low aircraft altitude, and vectored a left turn to heading 180 degrees. As the airplane rolled into the left turn, the rate of descent increased dramatically. It is at this point that the cockpit voice recorder documents the FO's confused remark: "We did something to our altitude."

"What?" the Capt. abruptly asks.

The FO voice is heard again: "We're still 2,000, right?"

Just before the sound of the initial impact of the aircraft into the ground in heard, the Capt. voice echoes his confusion: "Hey, what's happening?"

The cockpit voice recorder recorded the sound of six beeps indicating that the aircraft was dangerously close to the ground. The initial impact of the aircraft into the ground was recorded.

The Captain, First Officer, and Flight Engineer died. Ninety-four passengers and three flight attendants also died on Flight 401. It took just over eight minutes for the malfunction and attempted resolution to cause this accident.

The National Transportation Safety Board determined that the probable cause of this accident was **the failure of the flight crew to monitor the flight instruments during the final four minutes of flight**, and to detect the unexpected descent soon enough to prevent impact with the ground (NTSB 1973).

Under the FAA's regulation of manufacturing, maintenance, and operations, the aviation industry has maintained a high level of safety since the mid-1960's. Nevertheless, when an airplane has an accident, there is usually catastrophic loss of life and material damage. A large airplane accident can cause more deaths than almost any other type of event, apart from war and natural disasters. Because of this there is a tremendous public and media interest in aviation safety.

During the past 30 years, the number of departures by airline aircraft has more than quadrupled from approximately four million worldwide in 1967 to approximately 16.3 million in 1997 (Flight Safety Digest,1998). Worldwide flights are expected to increase from 16.3 million in 1997 to more than 25 million by 2010. If the current accident rate is projected over that traffic level, the number of accidents can be expected to increase to where there is a large jet aircraft accident every seven to ten days somewhere in the world. Within the United States, the existing accident rate coupled with expected traffic growth would lead the number of catastrophic accidents to rise from the current total annual level of 3-4 and increasing to 6-7 by 2010 (Flight Safety Digest, 1998).

HUMAN FACTORS ISSUES

The Boeing Commercial Airplane Group (1997) analysis of all commercial jet accidents worldwide over the past 10 years found that approximately 72 percent of errors were caused primarily by the flight crew. Therefore, any strategy to bring reduction in the accident rate must include government and industry programs that endeavor to reduce human error. Although human error is complex and the causes are more intricate to solve than a mechanical failure, research in human error and performance brings the aviation industry closer to predicting possible problems.

The study of human factors in aviation safety has progressed over the years from the identification of pilot errors influenced by aircraft designs. Beyond the cockpit design, some pilot errors can be traced to lapses of attention, poor situational awareness, forgetfulness, abnormal situations, distractions, high workload, and inadequate training. A pilot's lack of aircraft knowledge or performance skills may lead to unsafe flight conditions. One of the major goals of human factors research is the reduction of human error and development of means to alleviate the consequences of these errors.

RESEARCH ISSUES AND OBJECTIVES

Flying an aircraft requires the pilot to perform multiple, concurrent tasks classified as

- Aviate tasks: those tasks concerned with the control of the aircraft's motion;
- Navigate tasks: those tasks concerned with determining the present location and how to arrive at an intended location;
- Communicate tasks: those tasks concerned with transmitting information to or receiving information form another human, such as

an air traffic controller (ATC); and

- Manage systems tasks: those tasks concerned with the operating the aircraft's secondary equipment, such as its electrical system, hydraulic system, etc.

The process of managing these tasks is inherently well understood by pilots and almost always performed satisfactorily (for example: the Aviate, Navigate, Communicate, Manage Systems (ANCS) hierarchy).

Funk (1991) refers to the management of cockpit activities as "Cockpit Task Management" (CTM). CTM functions include the initiation, monitoring, prioritization, allocation of resources, and termination of these tasks. Due to the increasing complexity of modern aircraft, human errors will occur during these tasks, and during task management activities as well.

CTM is the process by which pilots selectively attend to and prioritize flight tasks in such a way as to safely and effectively complete the flight. The cockpit is a dynamic system, and the status and attentional demands of each task change with relative importance to flight safety.

Successful CTM requires effective task prioritization based on the tasks' importance to flight safety (e.g. maintaining altitude vs. talking to a passenger), urgency of the tasks (e.g. calling the final approach fix vs. calling an intersection during cruise), and how well the tasks are actually being performed (e.g. cleared to 5000, and altitude is 5050 and stable vs. altitude at 5150 and climbing). A task prioritization error occurs when the pilot does not give attention to the higher priority tasks– i.e., tasks more important to flight safety, more urgent, or not being performed at a satisfactory level – by attending to a lower priority task – i.e., one less critical to safety, less urgent, or already being performed well and is not in need of immediate attention. There are many documented instances, such as incidents and accidents where tasks were not managed properly, resulting in an aircraft mishap, such as the unfortunate example with Flight 401,provided earlier.

Reduction or prevention of human error in the cockpit can be approached through the improvement of the human-system interface, a technological solution, or through the improvement of pilot training, a human performance solution.

By making pilots aware of the potential for task prioritization errors and of situations that have, in the past, led to accidents and incidents, and by providing CTM training and techniques, I believe that the pilot's cockpit task management performance can be improved.

OVERVIEW OF THESIS

The research described in this thesis investigated pilot CTM training, and more specifically, the effectiveness of CTM training on task prioritization performance in simulated flight. Additionally, memory recall and malfunction resolution performance was assessed to determine CTM training effectiveness.

Chapter 2 consists of the literature review necessary for understanding safety concerns and human performance issues, task management, cockpit task management research, and approaches to facilitate pilot performance. The chapter concludes with discussion of the research objective.

Chapter 4 provides a description of research methodology and description of the flight simulator.

The description of the results and discussion are presented in Chapter 5 and Chapter 6, respectively. In addition, Chapter 6 also discusses contributing factors found in the results.

Chapter 7 provides the conclusions of the research and recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

INTRODUCTION

Air transportation over the years has been demonstrated as a safe means of travel, although aircraft incidents and accidents still result. Boeing's statistics of commercial jet airplane accidents reveal that flight crew errors accounted for 70% of the 149 hull loss accidents (destroyed aircraft) in worldwide commercial fleets through the period of 1988-1997. Aircraft safety has become an important issue to the aviation community and the public. Current commercial aircraft are equipped with sophisticated technology to aid in achieving a safe flight, but accidents still occur with disastrous consequences. If the current accident rate remains unchanged and traffic growth continues to increase, there is a real risk that public confidence in air transportation could be diminished. About 60 to 90 percent of accidents and incidents in complex systems, such as an aircraft cockpit, are attributed to human operator error (Reason, 1990; Wickens, 1992).

COCKPIT SAFETY CONCERN

The aircraft cockpit has become a complicated and advanced system, and this leads to new problems and concerns in the ability of a pilot to effectively manage this complex environment. In full mission flight simulator studies on pilot errors, vigilance, and decision-making, it was found that the pilot's lack of the ability to effectively manage cockpit resources and instruments was a common cause of errors (Ruffel-Smith, 1979).

In the cockpit, a pilot performs multiple and concurrent tasks to accomplish a flight mission. For example, the pilot may have to simultaneously level the aircraft at an assigned altitude and switch communication frequency to talk with air traffic control (ATC) while reviewing an approach plate for landing. The pilot acts as a system manager: monitoring systems, allocating resources to systems, and making decisions to perform individual cockpit tasks. Funk (1991) referred to this management role performed by the pilot as Cockpit Task Management (CTM).

Funk (1991) developed a normative theory of CTM to describe pilot activities in the cockpit. He defined CTM to include: creating a task management (TM) agenda, assessing the situation, activating tasks, assessing progress and status of active tasks, terminating tasks, assessing task resource requirements, prioritizing tasks, allocating resources, and updating the TM agenda. Therefore, CTM activities include the initiation, monitoring, prioritization, and resource allocation of concurrent flight tasks. Pilot errors will not only occur while executing these tasks, but will also occur while managing tasks in the cockpit. CTM errors occur when pilots fail to perform CTM functions satisfactorily.

Since the number of tasks in the cockpit may exceed the limited capacity of pilots' resources, effective CTM requires the proper allocation of attentional resources to tasks most crucial for the safety of the flight. As noted earlier, the cockpit is a complex multi-task environment, which requires proper CTM for a safe and effective flight mission. The following sections in this chapter discuss issues related to CTM such as attention, task management performance, CTM errors in accidents and incidents, training research, and aids to facilitate CTM performance.

ATTENTION

Although pilots can perform some activities automatically, many others require them to pay attention, which means concentrating and focusing mental resources. One critical aspect to CTM is the successful selection and allocation of attention. Selective attention pertains to the ability to focus mental effort on a task that is important in a particular situation (such as maintaining altitude) while excluding other stimuli (such as talking to passengers). When selective attention fails, pilots have difficulty ignoring information that is irrelevant to their high priority tasks.

Successful allocation of attention requires not only selectivity but also flexibility. For example, if ATC gives pilots new instructions, they must shift their attention from their current task and comply with new instructions. At any moment pilots can shift their attention from one task to another, virtually at will. Problems occur when a pilot is unable to focus attention on the tasks of high priority rather than those that are of lower priority. Pilots may focus on lower priority tasks to the exclusion of the instructions given by ATC.

Research indicates that voluntary control of attention is a trainable skill and can be improved through the use of techniques such as variable-prioritytraining (Gopher, 1992). In a cockpit, pilots' attention allocation and workload is critical to a safe and effective flight mission. At a fundamental level, cockpit task management is essentially the control of attention, proper allocation of attention, and attention-switching among the multiple tasks performed in flight. Allport (1992) comments that the nature of attention allocation in a multiple task environment is complex, and depends upon such factors as the nature of the task, the training, experience, and the abilities of the performer.

Training to allocate attention in multi-task environments, like the cockpit, can better facilitate the pilot's ability to do it successfully. Pilots follow a hierarchy of Aviate-Navigate-Communicate-Manage Systems (ANCS), and each demands attention. Learning to increase CTM performance requires ability to effectively shift attention among the multiple competing tasks of ANCS as a whole.

Allocation of Visual Attention

Visual attention uses the attention resources fundamental to CTM performance. A common metaphor for visual attention is the spotlight metaphor, a theory which holds that we can move our attention around to focus on various parts of our visual field (environment). Research on the size of this spotlight suggests that it can span varying degrees of visual focus (Erikson & Yeh, 1987). The smaller the visual focus, the better it can process any part of it. The spotlight can be focused so that it spans only a few objects in the visual field. Focusing the spotlight gives maximal processing to that part of the visual field, but if the person wants to process material in other parts of the visual field, it is necessary to move the spotlight, and this will take time to shift attention (Erikson & Erikson, 1974). In the cockpit, a pilot shifting attention from one task to another is similar to the spotlight metaphor.

In their 2000 study, Itti & Koch (2000) explain the mechanisms of visual attention based on a concept of a saliency map. A saliency map is an explicit two-dimensional map that encodes the saliency or conspicuity of objects in the visual environment. The model can be applied to common psychophysical stimuli as well as to a very demanding visual search task. A model of saliency-based visual attention adapted from Koch & Ullman (1985) highlights how the visual features of color, intensity, and orientation are computed in a set of pre-attentive perceptual feature maps based on retinal input. The authors explain a "winner takes all

network" that detects the most salient stimuli among the feature maps, and directs attention towards it. Certain technologies in the cockpit, such as alarms, signals, communication devices, and instruments, may attract the pilots' attention, distracting them from high priority tasks.

Milburn & Merterns (1997) conducted an experiment that suggests that blinking targets are more alerting (noticeable) than steady targets in air traffic control (ATC) display environment. The blinking targets helped the user find targets (aircraft) quickly and easily. The authors suggest that correctly manipulating target size, color, shape, brightness, contrast, and frequency of blink aids in simplifying the ATC display. The objective of their research was to recommend the level of blink amplitude that can capture the user's attention with a high degree of regularity (at least 95% of the time).

From these studies, we can infer the importance of visual attention and saliency of stimuli in drawing pilots' attention to particular tasks in the flight deck.

Interruptions in Pilot Attention

Pilots act as managers of multiple tasks in complex and dynamic environments. An aspect of multiple-task management (MTM) is interruption management. Latorella (1996) investigated an aspect of multiple-task management and interruption management in an operational context. Her study indicates that humans do not handle interruptions easily. Latorella gives four approaches to investigating interruption management:

1. Development of a theoretical framework for MTM, including interruption management.
2. Laboratory studies aimed at understanding mechanisms of interruptions.
3. Human/machine interface evaluations using interruption-recovery as an evaluation metric.

4. Identification of interruptions as a causal factor in accident/incident analyses and field investigations.

In her study, fourteen commercial airline pilots each performed 16 approaches in a simulated commercial flight deck. ATC clearances interrupted subjects as they performed three procedures during these approaches. Common ATC interruptions were found to be significantly disruptive to ongoing procedure performance on the flight deck by producing significantly more procedural performance errors and increased flight path management activity. The research empirically quantified the disruptive influence of interruptions on the commercial flight deck. Latorella states, "the effects of ATC interruptions and data link presentations degrade performance on the flight deck, and in light of accidents and incidents attributable to flight deck interruptions, it is evident that further research is required to identify specific task, environment, and operator performance-shaping characteristics that modulate interruption management behavior." Her research introduced both the interruptions pilots face in flight, and the importance of the management of tasks in complex multi-tasking systems, such as the flight deck. She further states that "understanding of both the significance of the factors modulating interruption management improves our understanding of how humans manage multiple tasks, and provides a means for more sensitively introducing and integrating interrupting tasks in MTM context" (p. 253). Therefore, in the management of multiple tasks, it is also important to train pilots how to handle interruptions and distractions in the cockpit.

In the operational cockpit environment, pilots would benefit most if they could fully attend and respond to tasks concurrently. However, while we may be able to apparently perform several tasks at once, we can devote thoughtful, conscious attention to only one at a time (Adams, Tenny & Pew, 1991). Some compromises and priorities must be established along with attention-selection strategies in the multi-task cockpit environment.

TASK MANAGEMENT

Multiple task performance studies often involve experiments where participants attempt to perform two independent tasks simultaneously. Findings from these studies led to a theory called multiple resource theory (Wickens, 1992). The theory explains that human mental capacity can be viewed as a collection of limited, differentiated resources that must be allocated among competing tasks. Therefore, if a task receives full allocation of required resources, satisfactory performance results. When the resources are taken away from the task, satisfactory performance degrades. In the context of the cockpit, similar degradation results when pilots allocate attentional resources to multiple tasks.

An investigation by Raby & Wickens (1994) linked the study of decision making with that of task and workload management. They studied when people chose to perform tasks and how they chose to adapt to high workload periods. Their study showed that the higher priority the task, the more closely it was performed to the optimal time. Their study was an effort to obtain and model data on task scheduling and shedding (dropping tasks) by student pilots engaged in simulated flights in high-workload aircraft landing environments. The results indicate that breakdowns in task management occur, and at times are responsible for dangerous in-flight incidents. The researchers had 30 pilots fly three simulated landing approaches under conditions of low, medium, and high workload, created by varying time pressures and external communications requirements. Pilots strategically managed or adapted to the increasing workload. The pilots were found to sacrifice some aspects of primary flight control as workload increased. A key finding was that high performing subjects scheduled discrete tasks earlier in the flight, and shifted more often between different activities. Individuals monitor their current workload, and decide to shed or assume tasks, if workload is too high or too low, respectively, in order to maintain workload at a relatively constant level (Raby et. al., 1994).

There is increasing evidence of difficulties in unassisted pilot performance of task management, and it is anticipated that the complexity and scope of TM on future flight decks will increase (Rogers, 1996). Adams et al. (1991), states that

> To the extent that people can properly attend to such aspects of the system only one at a time, the resulting situation must be characterized by frequent interruptions, unplanned shifts of attention, and system-driven changes in purpose and modes of thought. In effect, as the scope and autonomy of machine intelligence increase, the scheduling and initiative for information and activity management is increasingly usurped from the human operator. But the ultimate responsibility for their safe and sound operation is not (p. 242).

While pilots perform individual tasks satisfactorily, the performance of multiple tasks may go beyond their ability in a complex system. In their review, Adams et al. highlight the very complex memory and information-processing interplay that characterizes human attempts to manage multiple tasks.

Schutte and Trujillo (1996) conducted a simulator study in which pilots faced with several critical system faults were forced to alter the flight plan and land at an alternate airport. Their results indicate that pilots who used CTM strategies achieved the most effective performance when in an induced multiple-task environment. They suggest that CTM is largely dependent on individual differences between flight crews and personal style. The activity of CTM appears to have a significant effect on how pilots deal with an abnormal situation. Additionally, interruptions and distractions play a significant role in pilots' CTM performance. Schutte and Trujillo conclude that training for normative CTM strategies should be incorporated into pilot training.

Rogers (1996) conducted a study to analyze the cognitive processes that make up flight deck task management, both from a normative and operational perspective. One of the objectives of his study was to identify how task management was perceived and executed by pilots in real-time flight deck

environments. The first part of the study aimed at understanding what task management means to pilots. To evaluate this, the participants (three retired pilots) were tested by reviewing 40 index cards, each describing a potential cognitive process during flight. The pilots were asked to describe what each task meant to them and separate them into piles based on the similarity between cards. In the second part of the study, the pilots were given a random sample from 55 flight task descriptions and asked to prioritize each task according to its status.

From his results, Rogers described TM activities under little or no time pressure as: pre-planning; building a mental model; monitoring; contingency planning; filling gaps with continuous pre-planning items; and performing tasks early to avoid real and potential workload bottlenecks were used to describe TM activities when the flight proceeded normally with little or no time pressure.

In an emergency or time-pressured situation, splitting duties (between the crew members); using a well-learned, well-rehearsed mental list of discrete items to be performed; doing time-critical high priority items; operating in 'real-time'; hurrying the pace of tasks; and deferring or dropping tasks were used to describe TM activities.

TM was driven by time. Tasks were divided into discrete real time tasks, discrete pre-planning tasks, and continuous or repetitive tasks. Rogers's study provides a link as to the cognitive aspect of CTM. These findings emphasize the need for a cognitive approach in aviation training and cockpit design to facilitate efficient cockpit task management.

However, pilot training programs have historically focused almost exclusively on the technical aspects of flying and not on individual pilot performance. These programs do not effectively relate to task management issues that are additionally important to safe flight operations. Many problems

encountered by the pilot or flight crew have very little to do with the technical aspect of operating an aircraft. Instead, problems are associated with poor decision-makingineffective communication, inadequate leadership, and poor task or resource management.

CTM RESEARCH

The process of managing flight deck tasks is intuitively well understood by pilots. Funk (1991) formalized this in a preliminary, normative theory called Cockpit Task Management. The theory hones the terms 'goal' and 'task' to a CTM-specific meaning. In his definition, a goal is a desired behavior of the aircraft and a task is an activity performed to achieve it.

CTM is a theory of how pilots manage and perform concurrent multiple tasks while in flight. Pilot CTM performance is a legitimate safety concern for all aircraft operations. Several studies described below have shown that CTM errors contribute significantly to aircraft accidents and incidents.

Error Taxonomy and Data Analysis of Accident Reports

The National Transportation Safety Board (NTSB) has an accident/incident database that is an official record of U.S. aviation accident/incident data and causal factors. An aircraft accident is an occurrence in which a person (occupant or non-occupant) receives fatal or serious injury or any aircraft receives substantial damage.

An NTSB error taxonomy research developed by Chou (1991) highlights aspects of CTM that can aid analysis of accident reports. The error classifications consists of the following functions:

- Task initiation: The initiation of tasks when appropriate conditions exist.
- Task monitoring: The assessment of task progress and status.
- Task prioritization: The assignment of priorities to tasks relative to their importance and urgency for the safe completion of the mission.
- Resource allocation: The assignment of human and machine resources to tasks so that they may be completed.
- Task interruption: The temporary suspension of lower priority tasks so that resources may be allocated to higher priority tasks.
- Task resumption: The resumption of interrupted tasks when priorities change or resources become available.
- Task termination: The termination of tasks that have been completed, that cannot be completed, or that are no longer relevant.

In a review of the NTSB accident records, Chou identified and classified 80 CTM errors in 76 of the 324 accident reports. His findings illustrate that CTM errors played a significant role in about 23% of the accidents reviewed. This data gives supportive evidence that CTM is a significant factor in flight safety. To support his conclusion, Chou also conducted a flight simulator study to elicit and observe CTM errors similar to those identified in the accident and incident analyses. The participants flew a low-fidelity flight simulator in several flight scenarios while their behavior in managing and performing concurrent flight tasks was observed. The results from an analysis of variance (ANOVA) showed that both mental resource requirements (with the combination of flight path complexity), and number of concurrent tasks create significant effects on task prioritization. This study confirms that increased resource requirements (i.e, workload) have negative effects on task initiation and prioritization performance, increasing the likelihood of CTM errors.

Incident Reports and Analysis of Cockpit Task Management

Madhavan (1993) revised the existing CTM error taxonomy based on a detailed analysis of the ASRS incident reports. Aircraft incidents involve factors that, in combination with other circumstances, might lead to accidents. An aircraft incident is an occurrence, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operations. The Aviation Safety Reporting System (ASRS) represents a collection of self-reports provided by flight crews, pilots, and ATC personnel on aircraft incidents.

Madhavan studied CTM errors in task initiatio, task prioritization, and task termination. His study provides some important and useful results that confirmed CTM errors as a significant factor in a large number of incidents. He found that CTM errors occurred in 231 out of 470 ASRS incidents (49.2%). In more detail, task initiation accounted for 145 errors (41.5%), task prioritization accounted for 122 errors (35%), and task termination accounted for 82 errors (23.5%). The results of his research have implications that are largely training-based as opposed to design-based. He presents the following guidelines to alleviate CTM errors:

1. Provide comprehensive crew education (at all stages of flying career) in CTM errors and associated cognitive limitations.
2. Provide structured crew training (at all stages of flying career) that optimizes training resources and pilot learning abilities.
3. Emphasize safety preparedness in all training sessions as the basis for all CTM (and other) exercises.
4. Provide the cockpit crew with a continuous assessment of task status and priority in the agenda and also allocate system resources accordingly.
5. Provide a holistic view of the aircraft state (system state) and its relation to the outside world (world state) to the pilot.

6. Provide training to Air Traffic Controllers in CTM and Crew Resource Management (CRM) concepts.

Overall, this research provides a good starting point for identifying the relative importance and consequences of CTM errors, and important implications for CTM awareness in aviation. Other studies conducted research factors that contribute to CTM performance.

Cockpit Task Prioritization Factors

Colvin (2000) states, "CTM appears to be a large part of the crew's role on the flight deck, yet understanding of it is in its infancy and design processes have yet to adequately address it. As the existing aircraft fleet is upgraded with new avionics technologies, and new aircraft designs are developed, the complexity of the human-machine interface continues to increase" (p. 5). Colvin's study sought to identify which factors pilots use to determine task priority, and towards which tasks they will allocate their attention. In his study, pilots flew arrival procedures in a part-task simulator. Two knowledge elicitation techniques (intrusive and retrospective) were used to probe the subjects for factors that influenced their attention prioritization scheme while performing multiple, concurrent flight tasks. His analysis resulted in the identification of 12 factors that affect task prioritization. Two factors that clearly emerged were task status, with a total of 51 instances (30%) reported, and task procedure, with 48 instances (28%) reported. In the middle range of frequently reported factors was verifying information, reported 13 times (8%) and importance, reported 12 times (7%). The remaining less frequently reported factors that affect task prioritization as reported by pilots, included: rate of change, needed information, urgency, time/effort required, salience of stimulus, consequences, resist forgetting, and expectancy.

In conclusion, his study provides a better understanding of the task prioritization processes in the cockpit multitask environment. The findings also help in the development of pilot training programs, by understanding factors affecting task prioritization, and enhancing CTM performance.

POTENTIAL RESEARCH SOLUTIONS

The current research seeks to ask: "What can facilitate a pilot's CTM performance and improve task prioritization?" The answer to this question has two approaches involving the human-machine system of the cockpit. The first approach is through development of training programs. The second approach is through development of technological aids (interface) in the cockpit. Both approaches have shown promising results in facilitating CTM performance. The next sections introduce research in technological developments, and research in pilot training to facilitate CTM.

Technological Research

The cockpit Task Management System (CTMS), created by Funk and Kim (1995), extended the theory of CTM to include pilot goal representation. Here they defined a "goal" in the context of the cockpit, as a desired aircraft or system state; and a "task" as a process to achieve a system goal. The CTMS system consists of a separate display interface used to help the pilot initiate, monitor, prioritize and terminate tasks.

A part-task simulator study was conducted to evaluate the CTMS system effectiveness. Pilot use of the CTMS resulted in a reduction in task prioritization errors, shorter duration of time in unsatisfactory aircraft control, faster response time to critical events, and increase in the number of tasks pilots completed.

A second approach to reducing CTM errors is through the implementation of another aiding system, the cockpit agenda manager (Funk et al, 1997). This has successfully demonstrated potential in reducing such errors. Funk's study utilizes the AgendaManager (AMgr), an agent based computational aid that operates in a part-task simulator. The AMgr keeps track of pilot goals by interpreting ATC clearance acknowledgments using a speech recognition system. For each goal, the AMgr monitored aircraft status information to determine if the corresponding task was being performed in a correct and timely manner. When the system detected a satisfactory performance of a less important (e.g. system management) task at the expense of a more important (e.g. aviate) task, it alerted the pilot by means of a visual display. Airline pilot participants performed better using the AMgr than with a conventional warning and alerting system. The results suggest that task management behavior can be improved by means of an aiding system.

These studies using technological approaches proved successful in improving CTM performance. But Funk (1997) states that such technological solutions to the problem pose substantial challenges. First, there are technical challenges, particularly in correctly recognizing pilot intent. Second, the cost of scaling up an experimental aiding system to the operational airline environment would be substantial. Third, certification of such a system would be a major hurdle as the operational version would be at least as complex as the flight management system used in modern commercial aircraft. Finally, even if these challenges were met, any new technology designed to solve a problem itself introduces certain problems that developers and users may not be able to anticipate.

Criticisms to such technological pilot aids has been that in periods of high workload conditions, when CTM is so critical, they may demand additional attention from pilots and distract them from performing other, more important, tasks.

Pilot Training Research

"The Effectiveness of Cockpit Task Management Training on Task Prioritization Performance in Simulated Flight" is the thesis topic for the current research. This entails that the experimenter believed training helps cognitive performance. This section provides examples and research to support the thesis topic.

It would seem that poor judgment, poor in flight decision-making, and poor CTM performance are some of the commonly assigned human errors contributing to aircraft accidents. The airline industry, while experiencing a much lower accident rate than general aviation (GA), has sought to address human factor issues in flight safety through the introduction of Crew Resource Management (CRM) training. Freedman & Michael (1998) summarize selected findings of a study that evaluated the relevance of multi crew CRM concepts to Australian single-pilot GA operations. Although there has been extensive research conducted into CRM for the airline multi-pilot crews, research into CRM for GA has been sparse. While many of the principles and concepts of commercial aviation CRM may be applicable to the single -pilot general aviation environment, others may not. CRM for single-pilot operations is defined as "optimizing the pilot's decision making process, through the effective management of all available resources, information, equipment and people, to achieve safe and efficient flight operations" (p. 3).

The traditional training focus in GA has been on the technical aspects of flight and on the individual pilot's technical performance. Freedman & Michael comment that the less clearly defined criteria of resource management, decision-making and other human factor issues have only recently been recognized as important indicators of overall pilot performance. The most common factors to emerge from research conducted into GA accidents and incidents are those of poor judgment and decision-making. Jensen (1995) defines aviation judgment as "the mental process used to formulate an aviation decision." An intervention that improves these processes has the potential to reduce the rate of accidents and incidents.

Evaluation was deemed to be the most difficult issue to address, particularly the establishment of criteria on which a valid evaluation process could be based. There is little support for the direct evaluation of an individual pilot, especially on a pass/fail basis. Freedman and Michaels comment that the evaluation of the efficacy of CRM training may be better achieved though indirect methods, such as the development of GA industry markers. Effective CRM training should reflect a reduction in the rate of accidents and incidents, especially those with a judgmental or decision-making contributing factor. This would initially start at improved pilot training and evaluations at all levels of the pilot's career.

Aircraft mishaps tend to be attributed less to mechanical failure and more to human error. In recent years, there has been a growing realization of the significance of the lack of crew coordination and situational awareness as contributing factors to multi-crewed aircraft mishaps. Along with this realization has come the understanding that training can help. Alkov (1991) states that a continuing problem in naval aircraft mishaps is the loss of situational awareness. This in turn leads to errors of disorientation, mid-air collisions, flight into terrain or water, getting lost and running out of fuel, wheels-up landings, flight into heavy weather, etc. Alkov defines situational awareness as the accurate perception of the factors and conditions affecting the aircraft and the flight crew during a specific

time period. "It is knowing what's going on around you, knowing what has happened in the past and its relation to what is going on now and its affect on the future" (p. 2). Conventional wisdom used to hold that judgment was something you were born with, and which could not be taught. Although judgment is difficult to put into concrete terms, the elements that influence decision-making can be taught to enable the student aviator to render decisions in a rational manner even under stressful conditions where workload is high.

Green (1999) researched the types of learning that best explain how learners are socialized to aviation through the use of simulation technology. The importance of this leads to the appropriateness of educational strategies in training devices that could provide ways to enhance pilot judgment as well as increase technical skills. How students learn to fly is likely to affect their subsequent performance. Simulation can be an effective way to address both technical skills and decision-making skills, but it has not lived up to this potential in the general aviation domain. According to O'Hare & Roscoe (1990), "although airline training departments have greatly advanced the use of flight simulators, with few exceptions general aviation pilot training is almost unaltered despite the mountain of research material supporting the conclusion that the system in place is outdated and no longer appropriate." While training devices are being used to prepare students for flight, they are simply not the same as an actual flight environment. Instructors may well view simulator instruction as safe, because there is no threat of immediate physical harm regardless of student action; the training device is planted firmly on the ground. Because of this, however, a student may not be able to recognize that the expectations for performance have changed when they transfer to the flight environment. Green states that in addition to offering decision-making courses after pilots are licensed, more effort must be placed in helping flight instructors understand the critical role they play in helping student pilots learn about the decision-making process. Since procedures are frequently introduced for the first time in the simulators, this means that simulators will play an increasingly

important role in teaching decision-making skills. This also means that flight instructors need more guidance in the effective use of simulators to achieve that purpose.

General Aviation has received very little attention in the area of cognitive skill training such as CTM. Barber (1999) designed a training course to improve the judgment and problem solving performance of GA pilots in the en-route flight regimen. Recent models for such skills were utilized, together with innovative Computer Based Training (CBT) and flight simulation technology, to implement a training methodology that would allow pilots to learn and practice a prescriptive strategy for confronting ill-defined problems. The CBT program was designed to give formal instruction in aviation judgment and problem solving techniques. The author establishes guidelines for the experimental analysis using a CBT program. The guidelines consist of a series of instructional units, namely:

1. Judgment concepts
2. Situational awareness
3. Problem diagnosis
4. Problem resolution
5. Decision making

Barber defined three experimental groups based on the training methodologies:

1. Control Group (no judgment training)
2. CBT Group (judgment training on CBT only)
3. CBT + Microsoft Flight Simulator (MSFS) Group (judgment training on CBT and MSFS)

The results provide good evidence for the effectiveness of judgment and dynamic problem solving training for GA pilots. The choice of basing the training course on a naturalistic decision making model has proven very effective in improving the subjects' cognitive skills. Subjects who received CBT + MSFS training showed much improved situational awareness, and were far more aware of what was occurring both inside and outside the cockpit. Barber states that "if the

'bottom-line' for a training course is to raise performance to a standard that is at least considered satisfactory, then this is further evidence of the success of the model utilized in this research" (p.528). In conclusion, the cognitive skills and strategies taught in the course should help pilots to better focus their attention, improve their information processing abilities, and become more aware of what is happening around them in flight. This will allow them to be better prepared to react to any abnormal and/or emergency situation that should arise.

Tsang (1996) studied the retention and the transfer of time-sharing skills (prioritizing and handling of multiple tasks) as a function of age and flight experience. Certain memory functions degrade with advanced age, but there is a small amount of data on the extent to which time-sharing skill is retained. Whether time-sharing is task-specific has important implications on issues of training and simulation fidelity. Fourteen participants between the ages of 30 and 70 performed two task batteries of flight relevant laboratory tasks. Half of the participants were pilots considered to have expertise in time-sharing. Results showed that the older participants retained their time-sharing skill as well as the younger participants. Pilots time-shared better than non-pilots in general. Positive transfer of time-sharing suggests that time-sharing is a skill that has a general component such as executive management that develops and improves with training and is transferable across time-sharing contexts.

It can be shown from the training research that pilot training has been an effective way to improve certain cognitive pilot skills and, therefore, it is potentially effective for CTM.

SUMMARY

Research in Human Factors, a multidisciplinary field devoted to optimizing human performance and reducing human error, identifies that inadequate system design or inadequate operator training can contribute to human error. The errors committed by humans in the cockpit are classified as pilot error. Aircraft accidents and incidents often have their origin in an erroneous human decision by a pilot or flight crew. CTM errors occur when pilots fail to perform CTM functions satisfactorily. Research findings strongly suggest that these errors can be reduced by training.

Up to this point, this chapter has covered substantial ground from aviation safety, cockpit environment concerns, attention, task management, pilot errors and understanding pilot CTM performance to potential solutions to improve CTM performance.

This current study seeks to assess the effectiveness of CTM training on task prioritization. By this, the study takes the pilot training approach as a potential solution to facilitate task prioritization performance in the cockpit.

RESEARCH OBJECTIVES

The objective of this study was to determine the effectiveness CTM training in reducing CTM errors, and more specifically, reducing task prioritization errors. The training was presented in two forms, a lecture format (descriptive training), and lecture plus mnemonic technique format (prescriptive training). The prescriptive format is hypothesized to improve CTM performance better than the descriptive format. The descriptive format is used to counter arguments that awareness of CTM by itself improves task prioritization performance, not the mnemonic technique.

Therefore, the hypotheses of the current study state that: "CTM prescriptive training will improve pilots' CTM performance, and more specifically, reduce task prioritization errors in a part-task simulator flight." Second, "CTM prescriptive training will facilitate prospective memory tasks." Third, "CTM prescriptive training improves malfunction resolutions."

CHAPTER 3: RESEARCH METHODOLOGY

INTRODUCTION

To determine the effectiveness of CTM training, pilots flew two full flight scenarios (pre-training/post-training) in a part-task simulator. Microsoft Flight Simulator (MSFS) 2000 was used to assess the effects of CTM training on task prioritization performance during CTM challenges within the flight scenarios. A video recording of the participants and the aircrafts instrumentation was reviewed, as a primary method, to identify task prioritization errors during challenges presented to the participant.

A flight data recorder in MSFS recorded altitude, heading, speed, radio frequencies, etc., which were reviewed as a secondary method to determine flight deviations during the scenarios.

Participants were randomly assigned to either a control group, a descriptive group, or a prescriptive group. A more detailed description of the groups follows later in this chapter. Participants flew two similar instrument flight rules (IFR) scenarios, Alpha scenario and Victor scenario, each lasting approximately 50 minutes. The order of flying the scenarios was randomly assigned to each pilot in each group, in order to compensate for learning effect. Therefore, a pilot would either fly the Alpha scenario first (pre-training) and the Victor scenario second (post training), or the Victor scenario first and the Alpha scenario second.

During the flight scenarios, the pilot received ATC (Air Traffic Controller) instructions from the experimenter verbally, and the pilot followed and responded as if in a real flight environment. The pilot viewed two monitors: one monitor which displayed the cockpit view with the instrument panel, and the second monitor which displayed the radio stack. The experimenter viewed a third monitor

that displayed the pilot's instrument panel, radio stack, a digital clock, and GPS (Global Positioning System) display to track the flight in progress. An office cubicle wall separated the pilot from the experimenter. After the second scenario was flown, the pilot answered a post-experiment questionnaire.

CHAPTER OVERVIEW

Chapter 3 is divided into two parts. The first half describes the part-task flight simulator, flight simulator controls, simulator setup, pilot tasks, flight recorder, and the flight scenarios. The second half of the chapter describes the experimental design, participants, training, flight scenario instructions, CTM challenges, CRM error identification process, training groups, and procedures.

FLIGHT SIMULATOR

The part-task flight simulator used in this study was Microsoft Flight Simulator (MSFS) 2000, running on a Dell Pentium III desktop computer connected to three monitors by way of three video cards. The flight simulator program was installed on the computer with a "Custom" installation option. This method gave the experimenter options of downloading particular geographical scenery files on the hard drive, and leaving the other files to run directly off the MSFS CD. With these options, the flight simulator program would retrieve the scenery files faster from the hard drive, resulting in better simulator performance. For this study, only scenery files of the Pacific Northwest region were downloaded on the hard drive.

MSFS 2000 additionally allows users to create new or modified aircraft instrument panels through the modifications of the code script in the aircraft folders. These options to create new or modified aircraft panel views were possible through the use of an SDK (Software Developers Kit) developed for third party add-on developers. These third-party developers create add-on products that enhance MSFS capabilities. The MSFS 2000 SDK can be found on the Microsoft Flight Simulator 2000 website in the Developer's Desk link: (http://www.microsoft.com/games/fs2000/devdesk_sdk_fs2000.asp). The SDK located on the website is an instructional manual that describes ways of creating new aircraft panels, scenery, terrain, and adventures. For this study, only the Panels SDK was downloaded, which explains how to create add-on gauges and panels for the aircrafts in MSFS 2000. It provides complete documentation of the panel system in MSFS 2000, and sample code for instruments that can be modified. Familiarity with C programming and understanding of aviation systems and terminology are useful to successfully use the Panels SDK. The Panels SDK additionally references information directed to an Aircraft Container SDK, which was also downloaded.

The Aircraft Container SDK provides information about the Flight Simulators' aircraft container system. It describes in detail the aircraft files and how they are used within MSFS 2000. The aircraft folders in the simulator program files list all the aircraft flown in MSFS 2000, which are programmed in C language code. This code references the aircraft systems, panels, panel views, and other instruments that can be copied and manipulated to create a new aircraft instrument panel.

For the purpose of this study, the Cessna 182 RG was copied and named "Cessna 182 RG (saher)". The 182RG (saher) incorporated additional panel views for the experimenter. This new modified aircraft was then listed as an aircraft to choose when selecting an aircraft in MSFS (Figure 4.1).

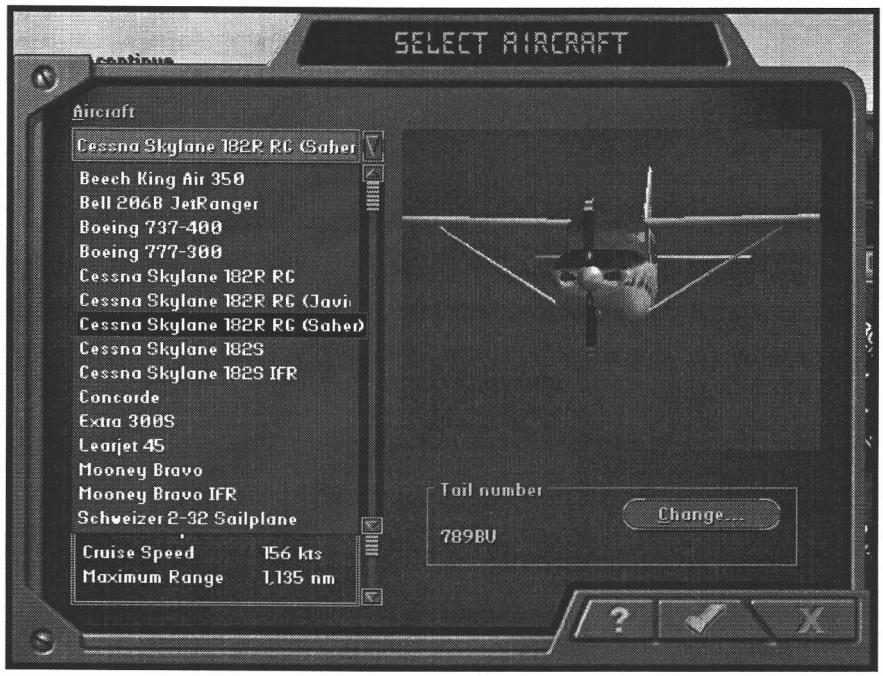

Figure 4.1: Aircraft Selection in MSFS

Within the panel code for the Cessna 182 RG (saher), there is a section the user can view, such as the compass, GPS, radio stack, etc. The additional panels required for this study were replications of a pilot's instrument panel, the radio stack panel, and a digital clock copied from another aircraft code and added to the aircraft panel views code. The additional panels were named and listed under the flight simulator "Views" pull down menu. The replicated instrument panel was named the "Auxiliary" view, the digital clock was named "Test" view, and the replicated radio stack panel was named "Radio Stackk" view (Figure 4.2 bottom right).

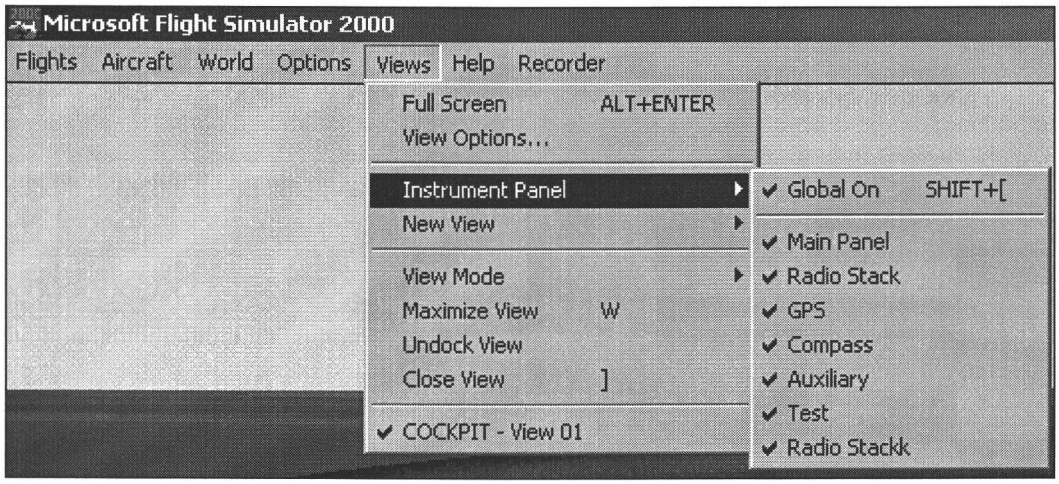

Figure 4.2: Panel views menu on the Cessna 182 RG (saher) aircraft

The new aircraft provided additional panel views for the experimenter to view on the experimenter's monitor. The "Auxiliary" instrument panel was a direct replication of the pilot's instrument panel viewed on the primary screen. Therefore any manipulations the pilot performed on the instrument panel would be seen on the "Auxiliary" experimenter's panel. The same was true of the "Radio Stackk" panel viewed by the experimenter, in that any changes the pilot made to the radio frequencies would be viewed by the experimenter. The "Test" panel view of the digital clock monitored by the experimenter provided a means of recording times of CTM Challenges during the flight scenario which could be traced in the flight data recorder. A GPS (Global Positioning System) map display was also used by the experimenter to monitor the track of the aircraft. Within the three monitors used for this study, pressing the right mouse button on any panel could undock the panel view, and then the panel could be dragged and placed onto any monitor.

A flight data recorder, obtained from the Microsoft flight simulator 2000 utilities website, was added to record aircraft data during the flight scenarios (http://www.simtakeoff.com/fs2000util.htm). The flight recorder provided the

experimenter a selection of aircraft state variables that could be recorded. (A list of all aircraft state variables that can be recorded is listed in Appendix 10). The flight data was used as a secondary measure to confirm flight path deviations, while watching the video recording of the flight scenarios was used as the primary measure to assess Task Prioritization errors.

MSFS provides options to assign to keyboard keys the ability to change aircraft systems, such as moving landing gear "Up" and "Down", turning systems "On" and "Off", and manipulating any control of the aircraft with the press of a designated key (Figure 4.3).

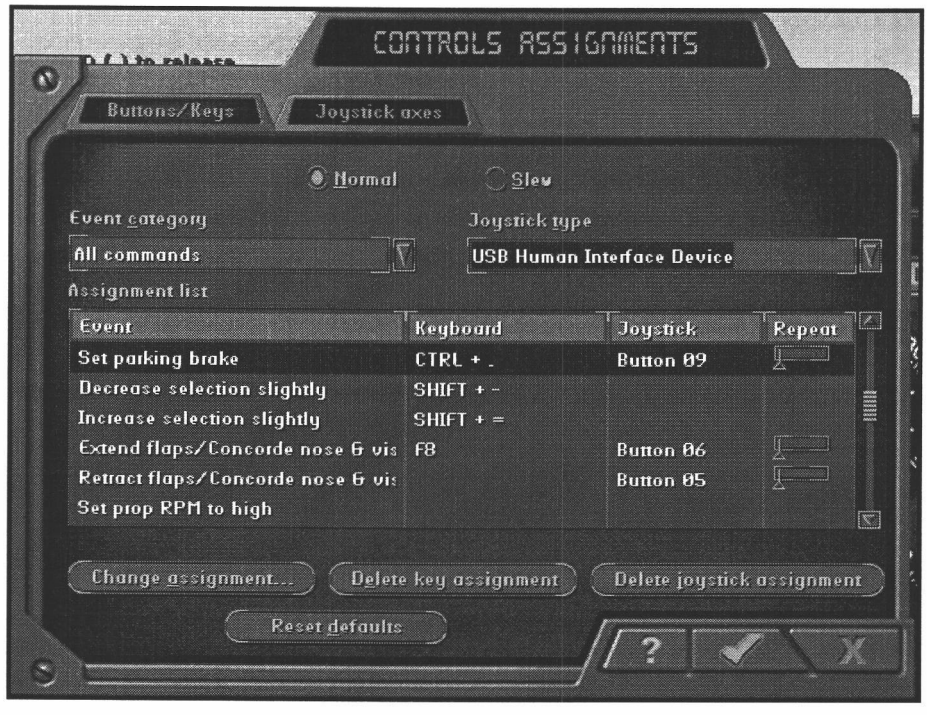

Figure 4.3: Key Assignments on MSFS

The keyboard key assignments used for the flight scenarios are listed on Table 4.1.

Table 4.1: Keyboard key assignments used by the experimenter

F1:	Master Switch (Alt side) "On/Off"
F2:	Fuel Pump "On/Off"
F3:	Pitot Heat "On/Off"
F4:	Carb. Heat "On/Off"
F5:	Cowl Flaps "Open"
#5:	Cowl Flaps "Close"
F6:	Propeller Lever Position "Out"
F7:	Mixture Lever Position "Lean"
F8:	Flap Position "Retracted increment
F9:	Gear Position "Up/Down"
F10:	Throttle Position "Decrease"
F11:	Primer "Toggle On"
Z:	Autopilot "On/Off"
Space Bar:	Smoke System "On/Off"
Pilot index finger button:	Nav 2 Ident. "On/Off"

The desktop computer running MSFS 2000 was a Dell Pentium III processor with 20 gigabytes of hard disk space, and 256 MB RAM. It ran the Microsoft 2000 operating system and connected to three monitors. The participants used an optical mouse to change the aircraft controls, and the experimenter used the keyboard to initiate malfunctions throughout the flight scenarios.

The desktop computer was installed with three video cards, allowing three monitors to display flight panel views. Of the three video cards, two were ATI video cards, and the third was a Vodoo video card. The Vodoo video card was connected to the primary 19-inch pilot monitor, and one ATI video card was

connected to the secondary 19-inch pilot monitor. The second ATI video card was connected to a 17-inch experimenter monitor. Additionally, both ATI video cards were connected to a Videonics Digital Video Mixer using video cables to transfer images from the monitor displays onto a TV monitor for recording on a VCR. The video mixer was additionally connected to a video camera that provided a front view of the participant flying the flight simulator. The mixer was connected to the VCR with video input cables, and the camera was connected to the VCR with the audio cable to record auditory communications during the flight scenario. The mixer allowed pictures of the experimenter view and the front view of the participant to be presented on the TV monitor, and this picture was through the VCR (Figure 4.4). The VCR recorded the entire session.

Figure 4.4: Picture in picture TV display from video mixer

The participant view on the T.V. monitor was adjustable in size and location by the video mixer for recording on the VCR. A diagram of the connections of the PC, monitors, video cards, video camera, video mixer, and VCR is provided in Figure 4.5.

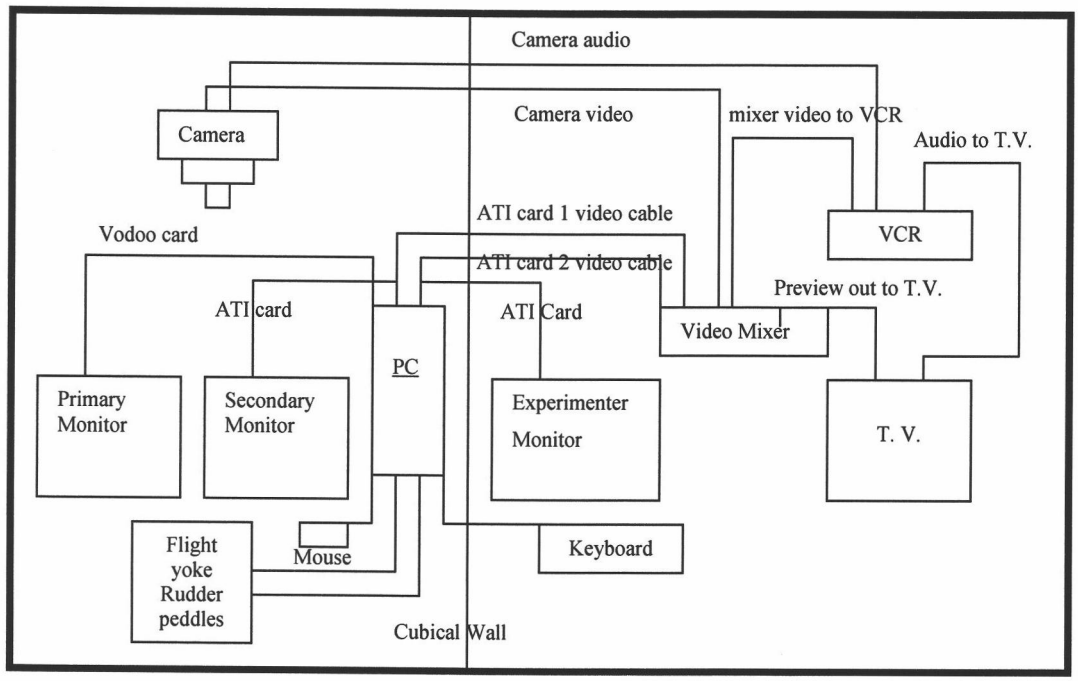

Figure 4.5: PC Connections

The aircraft was controlled with the use of rudder pedals, flight yoke, and a mouse, connected to the PC, to operate other aircraft systems. A more detailed description of the panel displays on the 3 monitors, the flight controls, and the simulator scenario setup is provided in the following sections.

Aircraft Flight Displays

The aircraft flown in the flight simulator, during each scenario, was a Cessna 182 RG (retractable landing gear) with one communication radio, one navigational radio, and DME (Distance Measuring equipment) for the station dialed on the navigational radio.

The participant's primary flight monitor displayed a "Cockpit View" of the instrument panel and an outside view of the environment (Figure 4.6).

Figure 4.6: "Cockpit View" on the primary monitor

On the instrument panel of the Cessna 182 RG, an Auto Pilot light located on the top left corner of the panel near the clock was used to alert participants of aircraft malfunctions (Figure 4.7).

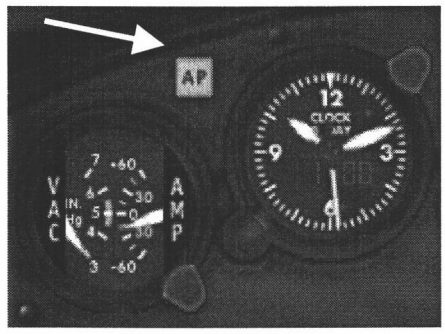

Figure 4.7: Auto Pilot (Alert Pilot) light

The Auto Pilot was not active during the flight scenario and the pilot did not have any means to control it. The AP light, controlled by the experimenter, indicated to the pilot if the system was "On" (light on) or "Off" (light off). When the system was turned "Off", an auditory signal sounded, warning a user that the Auto Pilot was disengaged. For the purposes of the present research, the Auto Pilot system was not used, although the Auto Pilot light and the auditory signal were used for experimental purposes.

The participants were instructed during training that the AP light was the "Alert Pilot" light, which illuminated when a control in the aircraft systems (Figure 4.8) was not as the pilot set it originally. For example, if the participant set the fuel pump "Off" after takeoff in the flight scenario, and the experimenter turned the fuel pump "On", the Alert Pilot (AP) light would illuminate. When the participant recognized the AP light illuminated, they tried to resolve the aircraft system malfunction. If resolved, the experimenter turned the AP light "Off", and the auditory signal sounded confirming that the malfunction was resolved. The experimenter controlled the AP light, along with the malfunctions, by pressing the assigned keyboard keys. For example, the experimenter pressed the "F1" key

turning the alternator switch "Off", and pressed the "Z" key to turn the AP light "On". Once the pilot resolved the malfunction, the experimenter pressed the "Z" key again to turn the AP light "Off", and the participant heard the auditory signal confirming that the malfunction was resolved.

The simulator could not duplicate the physical stimulation of the controls, nor the auditory feedback, that an actual aircraft would provide. Furthermore, graphical representations of the controls on the monitors could not easily be identified while performing a systems scan. Thus, the AP light was used to signal malfunctions.

The malfunctions the participants had to identify were introduced throughout both flight scenarios. When the AP light illuminated, this alerted the participants of systems such as the master switch, pitot heat, fuel pump, carburetor heat, cowl flaps, landing gear, flaps, etc., all displayed on the bottom of the instrument panel (Figure 4.8).

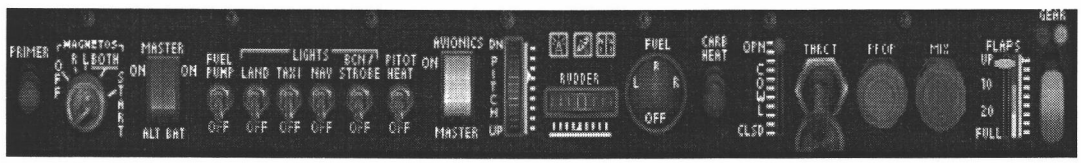

Figure 4.8: Systems on the Cessna 182RG

In order to resolve a malfunction, the pilot simply had to point the mouse cursor on the system malfunction and click the mouse button to resolve the malfunction. A more detailed description of the malfunctions used in this study is presented in the second half of this chapter.

The pilot's radio stack panel view for the Cessna 182 RG was undocked and moved to the pilots' secondary monitor. Figure 4.9 shows the radio stack on the secondary monitor, which was placed on the right side of the pilots' primary monitor.

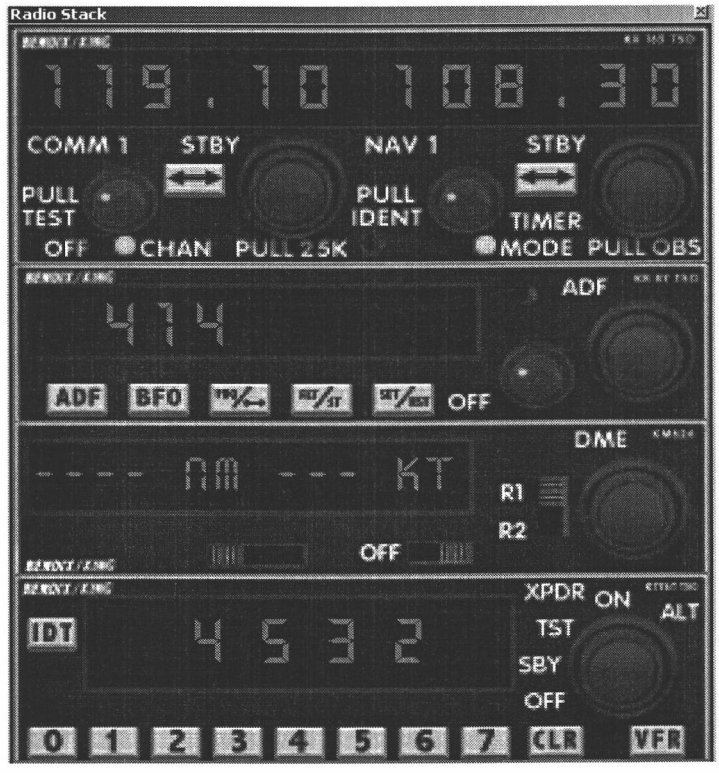

Figure 4.9: Pilot radio stack on the secondary monitor

The participant could change the frequencies on the radio stack by pointing the mouse cursor on the appropriate numbers and clicking the left or right mouse button. The participant changed the frequencies of the Comm1, Nav 1, ADF, and Transponder during the flight scenarios.

The experimenter's monitor allowed the experimenter to monitor the replicated views of the pilot's primary instrument panel and the radio stack. As explained above, the panels were undocked and moved to the experimenter's monitor located on the experimenter desk. During the flight scenarios, the experimenter could monitor the aircraft's flight characteristics, frequency changes on the radio stack, and control of the aircrafts systems. Additionally, the experimenter had the control to introduce system malfunctions, and to turn the AP light "On" and "Off" during each scenario. Therefore, the experimenter could monitor resolutions of system malfunctions in order to turn the AP light "Off", correct communication frequencies adjusted on the radio stack, and determine CTM errors during the scenarios. Figure 4.10 shows the view of the experimenter's monitor.

Figure 4.10: Experimenters Monitor View

Flight Controls

The flight controls used for this study were a flight yoke and rudder pedals made by CH Products. The flight Yoke was a Flight Sim USB Yoke with throttle, propeller, and mixture controls. The Yoke assembly additionally provided 4 buttons, 2 rocker switches, and 2 flipper switches (Figure 4.11).

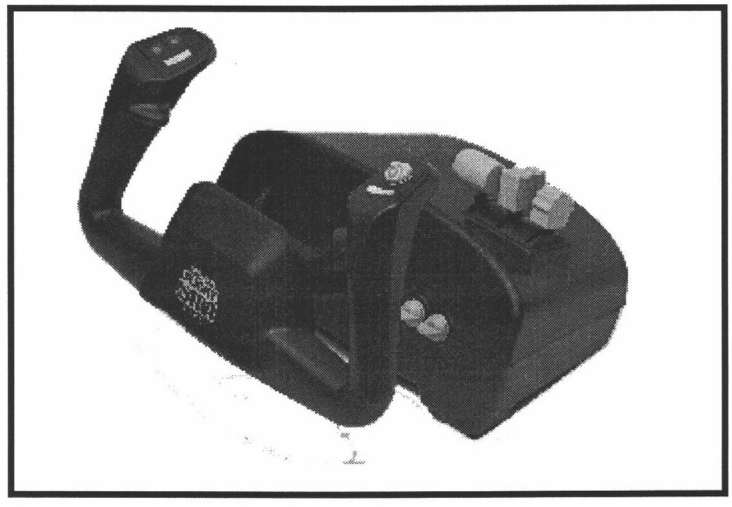

Figure 4.11: Flight simulator yoke

Within MSFS, the controls and buttons of the flight yoke can be assigned to particular systems that affect the aircraft, similar to the keyboard key assignments. The throttle, propeller, and mixture controls on the yoke assembly were assigned to the same systems on the Cessna 182 RG (saher) aircraft. The Flipper buttons were assigned to the flap control, and the landing gear control on the aircraft. The 8-way hat switch on the right side of the yoke was assigned as the point of view switch, which changed the pilot's view in the cockpit. The rocker switch on the right side of the yoke was assigned to the rudder trim of the aircraft. The rocker switch on the left side of the yoke was assigned to the elevator trim on the aircraft. The participants used the index finger button, on the left side of the yoke, as the microphone button, which was pressed down in order to communicate with ATC. This button was assigned as the "Nav 2 ident" button, because there was no option in MSFS settings to assign as the microphone button. As the "Nav 2 ident" button, this function was recorded within the data recorder to identify in the flight data file when the participant communicated with ATC. When the microphone button was pressed, it was recorded as "On", and when pressed again, it was recorded as "Off".

The upper button located on the left side of the yoke was assigned to setting the brakes "On" or "Off". The participants pressed this button to release the brakes when ready for takeoff. The control of the systems on the yoke assembly, such as the throttle, propeller, mixture, trim controls, flaps, and landing gear were directly correlated with movements on the aircraft's instrument panel view.

The pilot used USB Pro Rudder Pedals installed on the flight simulator for rudder control of the aircraft. The rudder pedals were assigned to the rudder pedal controls in the MSFS settings, but did not have an option for braking (Figure 4.12).

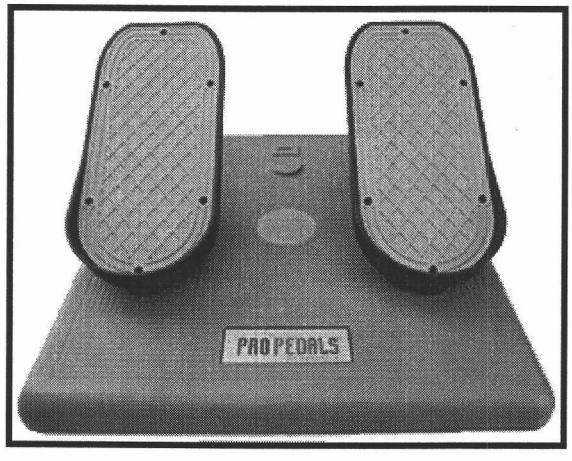

Figure 4.12: Rudder Pedals

Both the yoke and rudder pedals were adjusted for their sensitivities and realism settings through pilot studies before actual testing.

Flight Simulator Setup

The flight simulator was arranged on a desk with two monitors located side by side. The yoke was clamped to the center of the desk, and the rudder pedals were placed below the table. The participant had the ability to adjust the placement of both the rudder pedals and the seat for their comfort. The mouse was placed on the desk, or on the right side of the pilot at about the thigh level. The participant was allowed to place the mouse where comfortable. All participants were asked to bring their own flight gear to use in an actual IFR flight. Almost all participants brought yoke clips to hang approach plates, and kneepads as a place to write ATC instructions. If the participants did not bring their flight gear, a kneepad, IFR charts, and approach plates were provided. An additional chair was located on the right side of the pilot, acting as the passenger seat, on which the participant could place their flight gear. A 3-inch by 1-inch label of the aircrafts' call sign was placed on top of the primary pilot monitor for each scenario.

The weather was set up in MSFS to simulate IFR conditions, meaning that after takeoff and climbing to 500 ft. above ground elevation, the aircraft entered the clouds with no visibility of the outside environment. In MSFS, the user has the options of setting weather conditions, cloud layers, turbulence, wind speed/direction, and visibility. The weather was set up with no turbulence, calm wind, moderate rain, and cirrus cloud layers from 4790 ft. MSL (Mean Sea Level) to 7800 ft. MSL with ½ mile visibility in the clouds for both Scenarios (Figure 4.13).

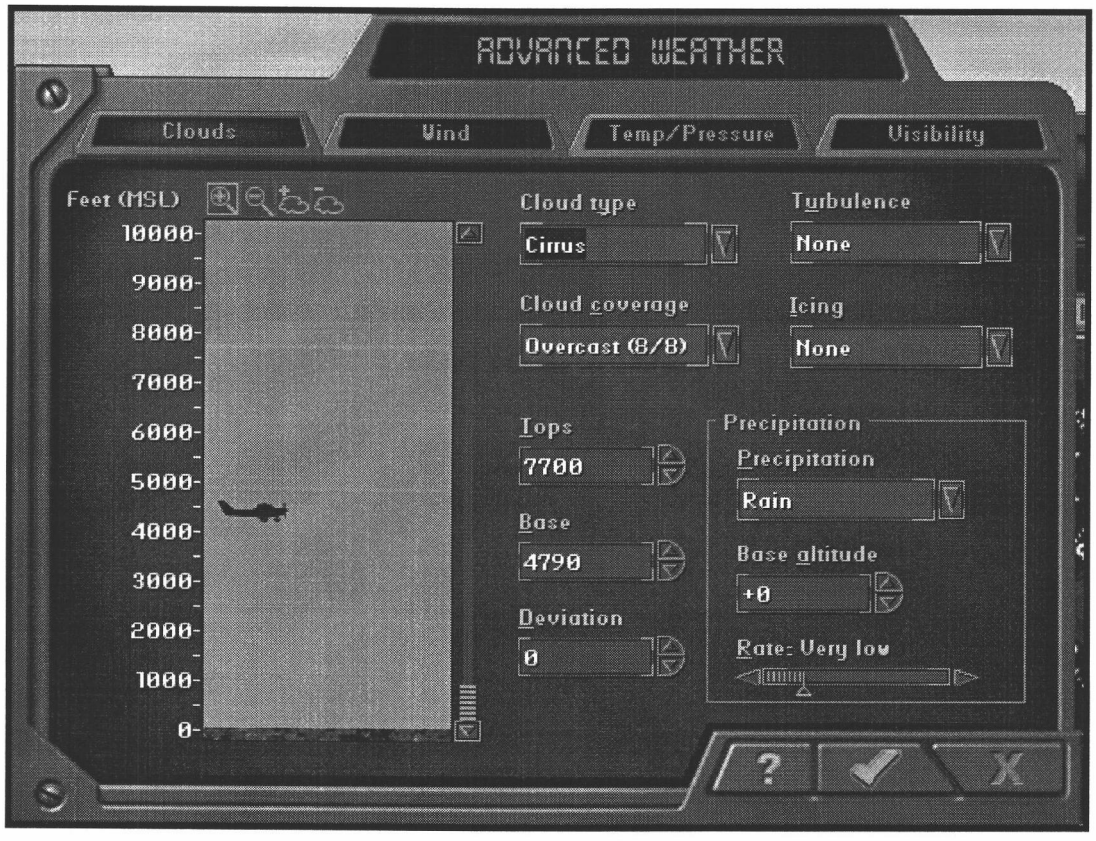

Figure 4.13: Weather Settings in MSFS

The experimenter's desk was placed on the right side of the flight simulator desk, separated by an office cubicle wall (5 ft. tall x 6 ft. wide). An additional office cubical wall was placed on the left side of the flight simulator desk. A camera on a tripod was located behind the wall and raised above it to record the participant's front view while flying the simulator. The experimenter monitor, keyboard, video mixer, T.V., and VCR were placed on the experimenter desk. Figure 4.14 shows the flight lab setup of the participant's station and the experimenter station.

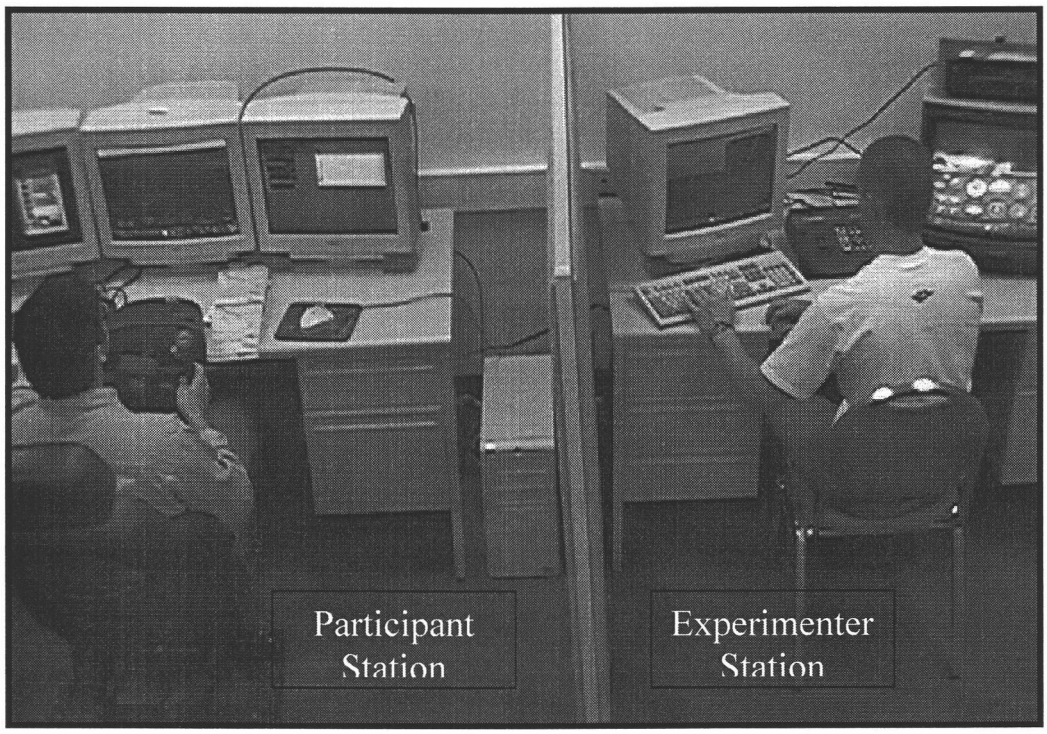

Figure 4.14: Participant Station and Experimenter Station

The experimenter monitored the pilot, aircraft characteristics, aircraft track, flight deviations, and CTM challenge times. The entire scenario was recorded from the experimenter's desk. The experimenter used the keyboard to initiate system malfunctions and illuminate the AP light. ATC communication throughout the flight scenario was made verbally by the experimenter and the pilot. Just as the pilot pressed the microphone button to communicate, the experimenter pressed the space bar when communicating to the participant. The space bar was assigned as the "Smoke System" in the MSFS settings, and recorded in the flight recorder. The experimenter pressed the space bar when communicating with the participant, and the smoke system was recorded as "On" in the flight data recorder. When communication ended, the button was pressed again to record the smoke system as

"Off" in the flight data recorder. This was done because MSFS settings do not have an option to record ATC communication points. The smoke system was chosen because it did not have an effect on the aircraft during flight. Therefore, within the flight data recorder, the ATC communication times, and pilot communication times could be identified in the flight recorder data.

Flight Recorder

The flight recorder installed on the MSFS recorded flight data variables of interest to this study. For the purposes of this study, only those variables of interest and applying to the Cessna 182 RG aircraft were recorded, and used for secondary analysis (Table 4.2).

Table 4.2: Flight Data

Clock Hour	Smoke enable	ADF Frequency
Clock Minute	Com Frequency	Nav1 Frequency
Clock Second	NAV1 VOR radial	NAV1 Morse Ident
Pitot heat	Aircraft Carb Heat	DME1 Distance
Transponder Code	VOR1 Needle	VOR1 TF Flag
VOR1 OBI	Airspeed	Vertical Speed
Stall Warning	Over speed Warning	Plane Latitude
Plane Longitude	Plane Altitude	Plane Bank Degrees
Fuel Tank Selector	Flaps Handle Pos	Gear Handle Pos
Charging Amps	Autopilot Active	Clock Total Seconds
Propeller 1 RPM	GPS Position LAT	GPS Positions LON
GPS Position ALT	GPS WP REQ HDG	GPS WP Bearing
NAV2 Morse Ident (Mic)	Marker Beacon State	GPS Ground Heading
Plane Heading Degrees Gyro	Engine1 Throttle lever Pos	Engine1 Propeller lever Pos
Engine1 Mixture Lever Pos		

Figure 4.15 shows the screen display of the flight recorder settings, with locations of data files and the option to choose the recording interval rate.

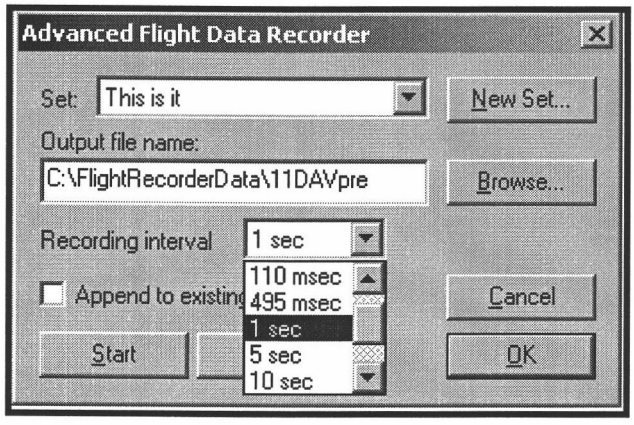

Figure 4.15: Flight Data Recorder Settings

For this study, the experimenter set a rate of 1 per second to record the flight data variables listed above. The file name was changed in each scenario to identify the participant number, group, flight scenario order, and pre- or post-training flight. For example, in the figure above, the output file name was C:\FlightRecorderData\11DAVpre. Only the characters after the second backslash (\) were changed. Therefore, the output file "11DAVpre" designated the participant number 11, group D (Descriptive Group), flight scenario order AV (Alpha first then Victor), and training flight Pre (pre-training flight).

Flight Scenarios

A flight planner, originally part of MSFS, was used to develop the flight scenarios. The flight planner allowed the experimenter to choose the departure airport, route of flight, intersections, alternate airport, and arrival airport (Figure 4.16).

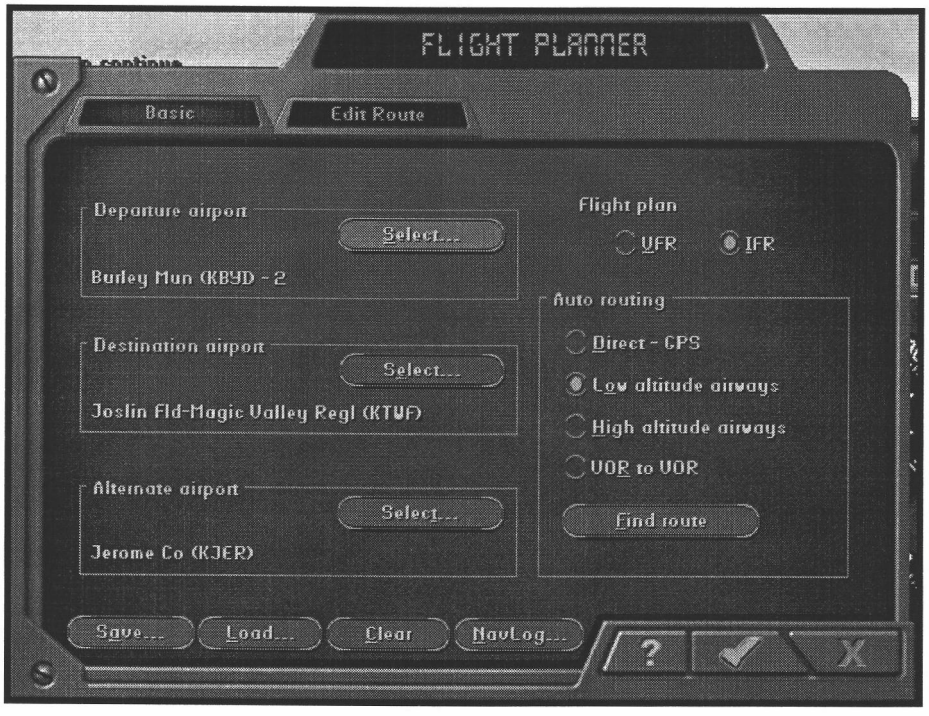

Figure 4.16: MSFS Flight Planner

Both flight scenarios were planned in the state of Idaho due to some unfamiliarity with routes and IFR approaches, and two airports were located that had equivalent IFR routes lasting 50 minutes. The practice flights before each scenario were conducted at the Pocatello, ID airport, and surrounding area (Figure 4.17).

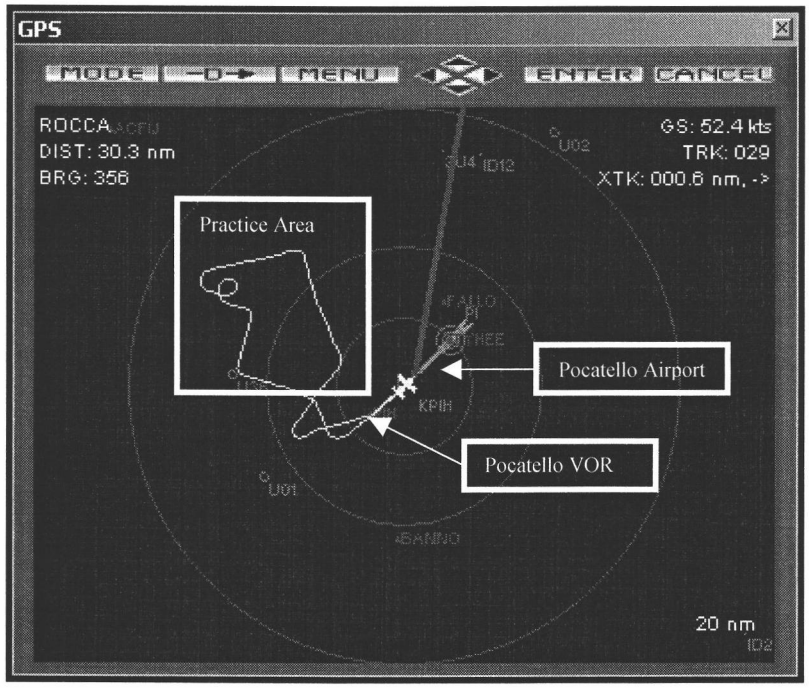

Figure 4.17: Practice Area

During the practice flights and both scenarios, the pilot communicated with ATC (played by the experimenter) verbally throughout each flight. Table 4.3 lists communications made by ATC and participants, from ground communications through arrival at the destination airport.

Table 4.3: ATC Communications

ATC communications:

1. ATIS: copy departure airport information.
2. Clearance delivery: Copy IFR clearance.
3. Ground control: Permission to taxi to the active runway.
4. Tower: Permission to take off.
5. Departure control: your contact with ATC in the terminal area.
6. Center: May talk to several sectors and possibly more than one center during the flight. For TEC routes you will talk to several approach control sectors and no center.
7. Arrival ATIS: copy arrival airport information. Try to listen on your second radio, or request permission to leave the center frequency for a minute.
8. Approach control: Approach clearance.
9. Tower: "Cleared to land.
10. Ground: Taxi to the ramp
11. Unicom: FBO parking instructions and request fuel

Before each scenario, the participants were given ATIS (airport terminal information systems) to receive general airport information, and the tower frequencies to receive permission to take off. They were instructed to disregard all communication frequencies in the charts and approach plates; the experimenter (ATC) would provide all of the necessary communication frequencies during the flight scenario. This was done because the pilots receive multiple communication frequencies, during CTM challenges, which are not the same as in the charts and approach plates. Therefore, in order to prevent any confusion between frequencies provided and listed in the charts, participants were instructed to disregard the published frequencies. The participants were instructed to use all navigational frequencies as listed in their charts and approach plates, pertaining to each scenario flight path.

Flight Scenario Alpha

Flight scenario Alpha was planned as a flight from the Burley municipal airport (KBYI) via Victor-444 to SHONE intersection, then direct to the Twin Falls municipal airport (KTWF) in IFR conditions. Figure 4.18 shows the GPS track of the Alpha flight scenario.

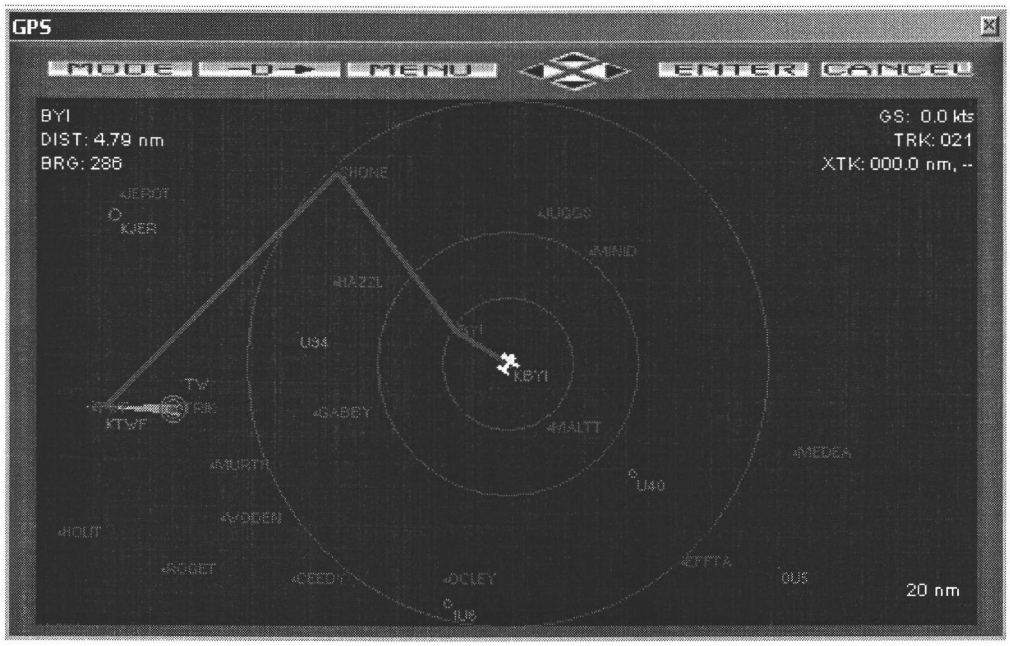

Figure 4.18: GPS track of Alpha scenario

The experimenter read the IFR flight plan for the route of the Alpha flight scenario to the participant. The participant was given as much time as needed to study the flight plan. The experimenter informed the participant that he/she would receive ATIS for Twin Falls by ATC while en route. After listening to ATIS, the participant dialed the Clearance Delivery frequency to receive initial departure

instructions after takeoff. The pilot then dialed the tower frequency to receive permission for takeoff from the runway. The pilot was instructed to skip contacting ground control for taxi permission, because the scenarios started on the runway. A flight scenario script was used (Appendix 8). During designated states of the flight, it led the experimenter to communicate or introduce system malfunctions and memory tasks to the participant. The Alpha flight scenario script gives further detail of the tasks and challenges presented to the participant.

The advanced weather setting in MSFS allowed the experimenter to set IFR flight conditions in the Alpha scenario. Figure 4.19 shows the advanced weather settings in MSFS for the flight scenarios.

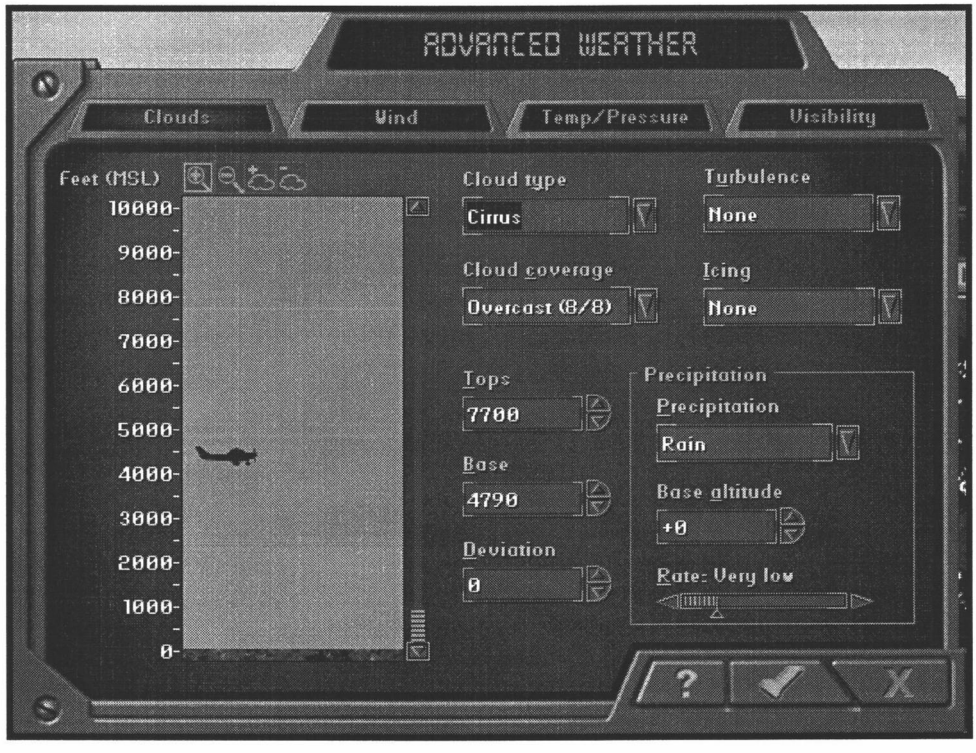

Figure 4.19: MSFS Advanced weather settings

The Alpha flight scenario script presented a total of 19 CTM challenges, 6 malfunction challenges, and 5 Memory challenges. The participant errors for each of the challenges were recorded on a CTM challenge checklist during the flight scenario (Appendix 7). At the end of each scenario, the error rates for the CTM challenges, the Manage Systems challenges, and the Memory challenges were recorded for each pilot. A more detailed discussion about these challenges is provided below.

Flight Scenario Victor

Flight scenario Victor was planned as a flight from the Twin Falls municipal airport (KTWF) via Victor-142 to OCLEY intersection direct to the Burley municipal airport (KBYI) in IFR conditions. Figure 4.20 shows the GPS track of the Victor flight scenario.

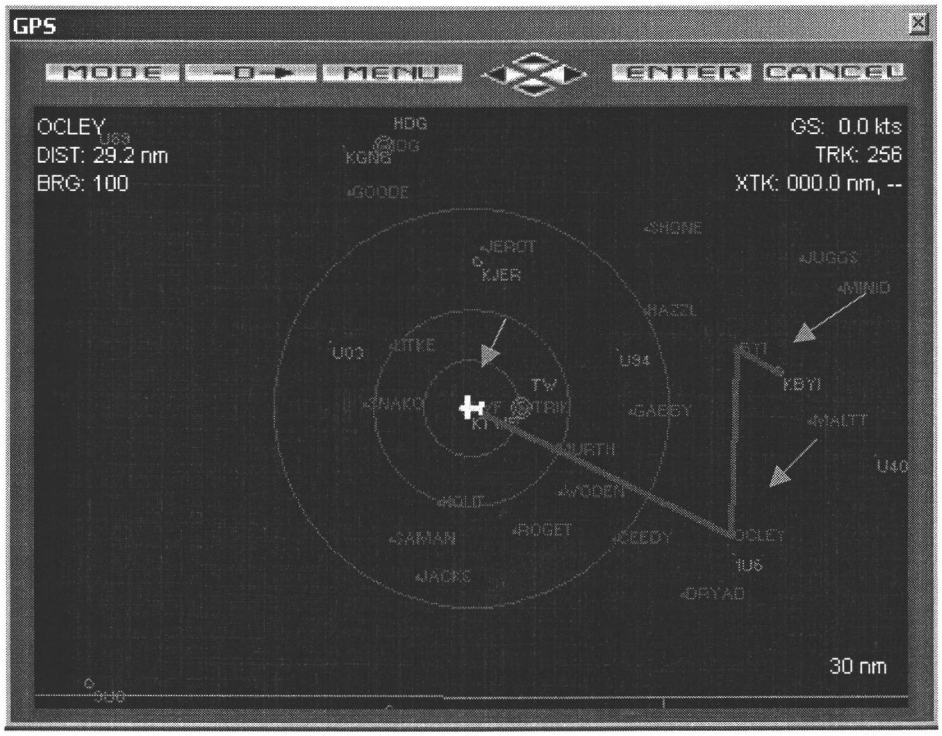

Figure 4.20: GPS track of the Victor flight scenario

The experimenter read the IFR flight plan for the route of the Victor flight scenario to the participant. The participant was given as much time as needed to study the flight plan. The experimenter informed the participant that they would receive ATIS for Burley by ATC while en route. After listening to ATIS, the participant dialed the clearance delivery frequency to receive initial departure instructions after takeoff. The pilot then dialed the tower frequency to receive permission for takeoff from the runway. The pilot was instructed not to contact ground control for taxi permission, because the scenario started on the runway. A flight scenario script was used (Appendix 9), to lead the experimenter. The victor flight scenario gives more detail of the tasks and challenges presented to the participant.

The weather in the Victor scenario was the same as in the Alpha scenario. The Victor flight scenario script presented the participant a total of 19 CTM challenges, 6 malfunctions, and 5 memory tasks. The participant errors for each of the challenges were recorded on a CTM challenges checklist during the flight (Appendix 7). The error rate for each participant was recorded for the CTM challenges, the malfunction challenges, and the memory challenges during the flight. A more detailed discussion about these challenges is provided in the second half of this chapter.

EXPERIMENTAL PROCEDURES

General Overview

This study set out to develop a simple, effective training method to increase a pilots' meta-cognitive ability in the cockpit (in particular, situational awareness and task management during multi-tasking demands simulated in a part task flight simulator). The goal was to facilitate the pilot's performance to properly identify, prioritize, and execute tasks.

The pilot CTM training was conducted in a lecture format, with simulator training. The descriptive group received a one-on-one lecture about CTM, examples of aircraft incidents and accidents, and situations of which to be aware in order to prevent CTM errors. A copy of the lecture content is provided in Appendix 4. The prescriptive group received the same lecture content as the descriptive group plus a mnemonic technique to facilitate Task Prioritization performance: "APE" (Assess, Prioritize, Execute). The pilot was introduced and

trained on the APE procedure (Appendix 5). The third group was a control group that did not receive any CTM training. A more detailed explanation of the three groups is given below.

The experimenter randomly assigned the participants into the three groups and to scenario order, flying either the Alpha (pre-training)/Victor (post-training) scenario order, or the Victor (pre-training)/Alpha (post-training) scenario order to prevent learning effects. Participants were introduced and trained on the simulator, flew the pre-training scenario, received (according to group) CTM training, and then flew the post-training scenario. A post-experiment questionnaire was administered to the participant to end the session (Appendix 3).

Participants

The participants for this study were 12 general aviation pilots holding at least a single engine land, instrument flight rating, with at least 100 hours "Pilot in Command" total time. Their age range was 20 to 72 with a mean of 46 years. Participants were recruited through the use of fliers at airports (Appendix 1) and word of mouth. They were recruited on a volunteer basis and were not compensated in any way.

Flight Simulator Training

All pilots were introduced to the simulator controls such as the rudders, flight yoke, and aircraft instrument panel, after which they received flight training in the simulator with instructions to follow after takeoff. The experimenter gave ATC instructions to follow, such as altitudes, headings, radial tracking, and vectors to landing.

The participants were presented system malfunctions, with the AP light illuminating. When resolved, the experimenter turned "Off" the AP light, and the audio signal confirmed resolution. The experimenter provided two to three examples of system malfunctions. The training ended with the experimenter providing radar vectors to landing at the practice airport. The participant was instructed to practice pressing the microphone button when communicating with ATC. If the participants did not feel comfortable at the end of the training, they were allocated more practice time on the simulator.

When the participants felt comfortable and capable of flying the IFR scenario, they received the first scenario flight plan and were given time to prepare for the flight. During this time, the experimenter loaded the flight scenario and named the data file on the flight recorder. The pilot then prepared the aircraft for the IFR flight.

Flight Scenario Instructions

The experimenter reviewed the airports, route of flight, navigational stations, and intersections with each participant in order to verify understanding of the flight plan.

All communication frequencies on the IFR charts and approach plates were disregarded, but all navigational frequencies were used as listed on the IFR charts. The pilot was instructed to disregard the SIDs (Standard Instrument Departure) and the STARS (Standard Terminal Arrival Routes) for both airports in each scenario. Clearance delivery provided initial departure instructions and approach control provided arrival instructions. The experimenter informed the participant that there would be no open conversation during the scenario, and any questions should be addressed to ATC.

Before takeoff, the pilot was instructed to dial in the ATIS frequency provided, and verbally call out "ready to copy ATIS". The experimenter then read out ATIS. Next, the pilot dialed in the clearance delivery frequency and called in to receive initial departure instructions from ATC after takeoff. The participant then dialed tower frequency to receive takeoff permission.

Experimental Groups

The experimental groups consisted of three groups, with four pilots randomly placed in each group and randomly assigned to flight scenario order. The pilot flew either the Alpha scenario as the pre-training flight and the Victor scenario as post-training flight (AV), or the Victor scenario as the pre-training flight and the Alpha scenario as the post-training (VA) flight. Therefore, within the four pilots in each experimental group, two flew the AV scenario order and two flew the VA scenario order. A copy of the randomly generated pilot group placement, and flight scenario order is provided in Appendix 6.

Control Group

The control group received flight simulator training and flew the pre-training flight scenario. The participants did not receive CTM training. A 40-minute break was allocated before flying the second flight scenario. After the break, participants received 30 minutes of training, by ATC instructions to follow after takeoff, such as altitudes, headings, radial tracking, and vectors to landing on an IFR approach. After training, participants flew the second flight scenario.

Descriptive Group

The descriptive group received flight simulator training and flew the pre-training flight scenario. Following this, participants then received CTM training in lecture format (Appendix 4). The experimenter read the lecture training material out loud while the participants followed along with their own copies. After CTM training, the participants took a 40-minute break. They then received 30 minutes of simulator training to review and put into practice what was covered in the lecture. During the practice, participants followed ATC instructions after take off, such as altitudes, headings, radial tracking, and vectors to landing on an IFR approach. After training, participants then flew the second flight scenario.

Prescriptive Group

The prescriptive group received flight simulator training and flew the pre-training flight scenario. They then received the same CTM training as the descriptive group, plus training in a mnemonic "APE" procedure (Appendix 5). The APE training procedure facilitated CTM in situational awareness and task prioritization performance. During the A P E procedure, the pilot would "Assess" the flight situation, "Prioritize" the concurrent tasks (ANCS hierarchy), and "Execute" the high priority task. The pilot was instructed to talk out loud throughout the A P E process (Figure 4.21).

The "Assess" stage was general in nature, meaning that the pilot would assess the environment, the flight plan, and the flight objectives. The pilot would verbally call out what he/she was doing at the present time and what steps he or she would take next. For example, "I'm leaving from Burley going to Twin Falls on the Victor-444 radial in IFR conditions, crossing Shone intersection then direct to Twin Falls". Another example would be, "I am on the Victor-444 radial, leaving

Burley, going to Shone intersection turning direct to Twin Falls for landing, in IFR conditions."

The "Prioritization" stage was specific to the aircraft characteristics and tasks performed during flight. The participant would evaluate and prioritize the ANCS tasks while in flight. Running through flight priorities, the participant first evaluated the Aviate tasks by asking, "Is the aircraft in control: on the right altitude, heading, speed?" Second, he/she evaluated the Navigational tasks by asking, "Do I know where I am and where I'm going?" Third, he/she evaluated the communication tasks by asking, "Do I need to report or receive information?" Fourth, he/she evaluated the Manage Systems tasks by asking, "Are my systems okay?" After evaluating the ANCS tasks, the participant identified the tasks to which "No" was answered, and set them as the high priority tasks to execute.

To improve Cockpit Task Management, let the A P E help you.

A P E

Assess Prioritize Execute

Assess the situation: Aircraft systems, environment (internal/external), tasks and procedures. **"What's going on?" "What should I be doing?"**

Prioritize your tasks: **Aviate, Navigate, Communicate, Manage Systems, (ANCS).**

1. **Aviate**: Fly the aircraft, maintain heading, altitude, and speed, control the aircraft within operational limitations.

- **"Is my aircraft in control? Right altitude, heading, and speed?"**
- If "No", then Aviate is high priority.
- If "Yes", then proceed.

2. **Navigate**: Know where the aircraft is and where you are going.

- **"Do I know where I am, where I'm going, and how to get there?"**
- If "No", then Navigate is high priority.
- If "Yes", then proceed.

3. **Communicate**: With ATC, FSS, other Aircraft, etc. to receive or report necessary information.

- **"Have I reported or received necessary information?"**
- If "No", then Communicate is high priority.
- If "Yes", then proceed.

4. **Manage Systems**: Monitor, operate, engine(s), electrical system, aircraft instruments, Nav/Comm equipment, etc. Manage cockpit.

- **"Are my systems okay?"**
- If "No", then Manage Systems is high priority.
- If "Yes", then proceed.

Execute the high priority tasks Now. Then reapply A P E.

Think out loud

Figure 4.21: APE procedure

During the "Execute" stage, the participant executed the high priority tasks in the hierarchical ANCS order. Therefore, if the Aviate and the Communicate tasks were high priorities, the Aviate task (controlling the airplane) was first stabilized, followed by the communication task. If the Navigate and Communicate tasks were high priorities, the navigate task would first be executed followed by the communicate task.

Talking out loud was necessary through the A P E process to provide additional memory recall of concurrent tasks during flight. A stamp-sized picture of an APE was given to the participant to place anywhere on the primary monitor as a memory aid (Figure 4.22).

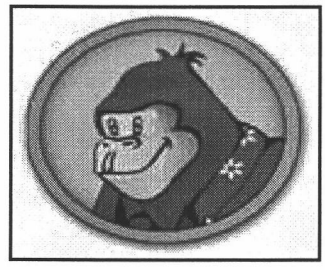

Figure 4.22: APE Picture

The experimenter advised the participants that the A P E procedure should be conducted during the instrument scan, during ATC communication, and crossing navigational fixes. After the prescriptive lecture training, participants took a 40-minute break. After the break, participants received 30 minutes of simulator training practicing the A P E process. During the practice, participants followed ATC instructions after takeoff, such as altitudes, headings, radial tracking, and vectors to landing on an IFR approach. After training, the participant flew the post-training flight scenario.

Flight Scenario Script

Each flight scenario script (Appendices 8 & 9) was read word for word every flight scenario. Only when pilots asked questions or reported additional information did the script not apply. The script provided the experimenter information as to when, where, and how to introduce the CTM challenges to the participants during each flight scenario.

Challenges

An objective in this study was to select challenge points that could properly identify task prioritization errors committed by the pilot. Although the challenge points were different for each scenario, the number of challenges remained consistent, so as to compare the pre-training to the post-training flight scenarios. The major obstacle in creating the challenge points was in making them realistic enough that they were representative of actual IFR flights.

During each flight scenario, a total of 19 Task Prioritization challenges, six malfunction challenges, and five Memory challenges were presented to the participant. The dependent measures were: task prioritization error rate, resolution rate, and recall rate recorded during the flight scenarios.

The 19 Task Prioritization challenges listed in Table 4.4 were presented by the experimenter at predetermined aircraft states within each scenario.

Table 4.4: 19 CTM Challenges in Both Flight Scenarios

Flight Scenario Alpha Challenges	**Flight Scenario Victor Challenges**
1. Aviate vs. Communicate	1. Aviate vs. Manage Systems
2. Aviate vs. Communicate	2. Aviate vs. Communicate
3. Aviate vs. Navigate vs. Communicate	3. Aviate vs. Manage Systems
4. Aviate vs. Manage Systems	4. Aviate vs. Navigate vs. Communicate
5. Aviate vs. Navigate vs. Communicate	5. Aviate vs. Navigate
6. Aviate vs. Navigate	6. Aviate vs. Communicate
7. Aviate vs. Communicate vs. Manage Systems	7. Aviate vs. Communicate vs. Manage Systems
8. Aviate vs. Communicate	8. Aviate vs. Navigate vs. Communicate
9. Aviate vs. Navigate vs. Communicate	9. Aviate vs. Manage Systems
10. Aviate vs. Manage Systems	10. Aviate vs. manage Systems
11. Aviate vs. Communicate	11. Aviate vs. Communicate
12. Aviate vs. Communicate	12. Aviate vs. Communicate
13. Aviate vs. Communicate	13. Aviate vs. Communicate
14. Aviate vs. Manage Systems	14. Aviate vs. navigate
15. Aviate vs. Manage Systems	15. Aviate vs. Communicate
16. Aviate vs. Communicate vs. Navigate	16. Aviate vs. Navigate vs. Communicate
17. Aviate vs. Manage Systems	17. Aviate vs. Manage Systems
18. Aviate vs. Navigate vs. Communicate	18. Aviate vs. Navigate vs. Communicate
19. Aviate vs. Manage Systems	19. Aviate vs. Navigate
Total: Aviate vs. Communicate Challenges: 4 Aviate vs. Navigate Challenges: 2 Aviate vs. Manage Systems: 5 Aviate vs. Navigate vs. Communicate: 5 Aviate vs. Communicate vs. Manage Systems: 1	**Total:** Aviate vs. Communicate Challenges: 6 Aviate vs. Navigate Challenges: 3 Aviate vs. Manage Systems: 5 Aviate vs. Navigate vs. communicate: 4 Aviate vs. Communicate vs. Manage Systems: 1

These challenges tested the participant's ability to apply the ANCS hierarchy in multiple task situations. For example,

- Challenge #1 (Aviate vs. Communicate) presented two concurrent tasks to the participants. During a climb to a designated altitude, 20 feet before reaching that altitude to level off, the participant was requested to switch radio frequency to contact departure ATC. At this time, the participant had to both level off plane at altitude (Aviate) and switch communication frequency (Communicate). This challenge point determined whether the pilot attended to the lower priority task (Communicate) at the expense of the higher priority task (Aviate), and whether or

not the participant "busted" (exceeded) the assigned altitude. If the pilot overshot altitude by +/- 200 feet, the challenge was recorded as an error; but if the pilot leveled the plane first and switched communication frequency without "busting" altitude, no error was recorded.

- Challenge #15 (Aviate vs. Navigate) presented two concurrent tasks, with ATC informing the participant that the localizer for the ILS approach was out of service, and that the approach was revised for a VOR approach to landing. Therefore, at this point the participant had to maintain the aircraft (Aviate) while reviewing and adjusting navigational frequencies for the new approach (Navigate). If the participant attended to the lower priority task (Navigate) at the expense of the higher priority task (Aviate), and "busted altitude" or deviated from heading (VOR needle deviation of 2 or more dots), it was recorded as an error. If the participant maintained aircraft control (Aviate) while adjusting Navigational frequencies, then an error was not recorded.

- Challenge #4 (Aviate vs. Manage Systems) presented two concurrent tasks to prioritize. It gave the participant a system malfunction while tracking "to" the VOR. If, during the process of resolving the lower priority (Manage Systems) task, the participant deviated from altitude or heading, it was recorded an error. However, if the participant resolved the malfunction and maintained aircraft control, it was not recorded as an error. Additionally recorded during this challenge was the resolution of the system malfunction. It was possible that some participants did not identfy the AP light and did not resolve the malfunction until much later in the flight scenario. Therefore, the resolution rate determined the participant's identification and resolution of malfunctions.

- Challenge #9 (Aviate vs. Navigate vs. Communicate) presented three concurrent tasks to prioritize. When crossing the intersection ("SHONE" intersection), the participant was requested to switch frequency to another ATC. During this time, the participant had to maintain aircraft control (Aviate), get established on the next radial track to the arrival airport (Navigate), and switch

communication frequency. Therefore, if any of the lower priority tasks (Navigate and Communicate) affected the higher priority task (Aviate), it was recorded as an error. Within this scale, if the lower priority Communicate task affected the higher priority Navigate task, it was also recorded as an error.

The malfunction challenges presented to the pilot are listed in Table 4.5. If a participant had a particular system "On", the experimenter would switch it "Off" to challenge him/her. The same applied to systems that were originally "Up" or "Down".

Table 4.5: 6 Manage Systems Tasks in Both Scenarios

Flight Scenario Alpha Manage Systems Tasks	**Flight Scenario Victor Manage Systems Tasks**
1. (#4 in Scenario): Alternator "Off"	1. (#1 in Scenario): Carburetor Heat "On"
2. (#7 in Scenario): Fuel Pump On"/"Off"	2. (#3 in Scenario): Cowl Flaps "Open/Closed"
3. (#10 in Scenario): Reset Transponder	3. (#7 in Scenario): Alternator "Off"
4. (#14 in Scenario): Carburetor Heat "On"/"Off"	4. (#9 in Scenario): Reset Transponder
5. (#17 in Scenario): Flaps retracted 10 degrees	5. (#10 in Scenario): Pitot Heat "On"/"Off"
6. (#19 in Scenario): Landing Gear "Up"/"Down"	6. (#19 in Scenario): Landing Gear "Up"/"Down"

The experimenter presented malfunctions at predetermined times during the flight scenario. These malfunctions challenged the participant to allocate attention to resolve the malfunction in addition to performing the normal tasks of flight.

The memory tasks required the participants to call out aircraft locations as requested by ATC. These tasks involved prospective memory, in which a participant must remember to perform a task in the future. The memory tasks for both scenarios are listed in Table 4.6.

Table 4.6: Memory Tasks for Both Scenarios

Flight Scenario Alpha Memory Tasks	Flight Scenario Victor Memory Tasks
1. Report established on the Radial	1. Report crossing VOR
2. Report crossing intersection	2. Report crossing intersection
3. Report Crossing VOR	3. Report crossing VOR
4. Report Procedure turn outbound	4. Report Procedure turn inbound
5. Report 3 miles out	5. Report crossing VOR

Dependent Measures

Through review of the videotapes, the experimenter identified and recorded task prioritization errors, malfunction resolutions, and memory recall only during the challenges presented during the flight scenarios.

Task Prioritization errors were recorded during the challenges when:

1. The pilot deviated from the assigned altitude by (+) or (-) 200 feet.
2. The pilot deviated from heading, and the VOR center needle moved two or more dots from center position (Figure 4.23).

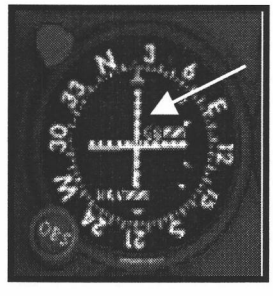

Figure 4.23: VOR Needle

3. During a climb to a designated altitude, the pilot descended 200 feet or more.
4. During descent to a designated altitude, the pilot climbed 200 feet or more.
5. While crossing a VOR, the pilot delayed a turn to heading by 3 miles or miles.
6. While crossing a VOR, the pilot delayed a requested climb for 3 miles past the VOR.
7. While crossing an intersection, the pilot delayed the turn to arrival airport for more than 3 miles past the intersection.
8. The pilot tracked the wrong radial after crossing a VOR.

System malfunction resolutions were recorded during the challenges when; The pilot resolved the malfunction task during the current flight phase or the first half of the next phase. They were recorded as unresolved if the malfunction affected the aircraft. For example, if the alternator switch was turned "Off", and it was not resolved within a certain time period, this led to a power failure.

Memory recall was recorded during the challenges when; The pilot reported aircraft positions as requested by ATC.

Therefore, 19 task prioritization challenges, six malfunction challenges, and five memory challenges were all recorded individually during each flight scenario. Results were based on three percentage rates for the three dependent measures (error rate, resolution rate, recall rate) between the pre-training and post-training flight scenarios.

Post-Experiment Questionnaire

After the second scenario, the participants finished the session by answering the post-experiment questionnaire. The experimenter recorded comments and suggestions regarding the study. The questionnaire was developed to gain an

understanding of the participants' characteristics. Total flight hours, total instrument time, ratings held, and frequency of flight gave an idea of the participant's flight activity level. The experimenter asked questions to determine if the participant had familiarity with computer games and MSFS, in order to find some potential simulator performance differences. Participants were asked whether they preferred to fly in day or night, because night flights rely more heavily upon instrument reference, whereas day flights call upon more outside reference. Additionally, comments on the experimental session and factors that may have affected their performance were recorded to determine any confounding variables.

Procedures

The total time to conduct the session for each participant was approximately 4 1/2 to 8 hours, depending on the experimental group and the amount of training time necessary for the pilot. The participants signed the informed consent document before proceeding with the study. A copy of the informed consent form is included in Appendix 2.

The first 20 minutes of the session were used for an overview of the procedures and schedule. The experimenter verified the participant's IFR license, currency, ratings held, and currency of medical certificate. The participants were asked if they had any medical conditions of which the experimenter should be aware. The amount of caffeine and the amount of sleep the pilot had was recorded to verify his or her ability to fly the simulator.

The participants were then trained on the simulator for 30 minutes, or until they felt comfortable. Each participant flew the first scenario and received the lecture training (the control group took a 40-minute break). Additional simulator training was conducted for 30 minutes, and then the participants flew the second flight scenario.

Data collection for the experiment consisted of three dependent measures in each flight scenario. The experimenter recorded the task prioritization error rate, resolution rate, and recall rate. The experimenter reviewed the videotape recordings for each scenario for data collection and reduction. If by any chance one of the dependent measures could not be identified by review of videotape, the experimenter reviewed the flight data recorder data.

Both scenarios were similar, yet different enough that a participant could not anticipate ATC communication, or report aircraft location and system malfunctions. The pilots were balanced so that half of the participants in each group ran the Alpha scenario first and half ran the Victor scenario first.

The experimental design was a mixed 2 X 3 ANOVA design for each dependent measure. The treatments were flight (pre-training, post-training) and group (control, descriptive, or prescriptive) in this study. The three ANOVA tests were for error rate, resolution rate, and recall rate.

CHAPTER 4: RESULTS AND ANALYSIS

OVERVIEW

This chapter presents the results and analysis of the study. The experimenter collected data from pre- and post-training flights on task prioritization error rate, resolution rate, and recall rate. This chapter includes a description of the data results and analysis conducted. The data for each of the three dependent variables was analyzed with identical mixed design (2 X 3) ANOVAs, with flight (pre-training, post-training) treated as a within-subject variable and group (control, descriptive, prescriptive) treated as between-subject variable. Post hoc tests isolated more specific differences between the groups. Commercial statistical analysis software called Statistica was used for all ANOVA calculations. Additional t-tests conducted for each individual group in each dependent variable compared means between flights. Information gathered from the post-experiment questionnaire is also discussed.

TASK PRIORITIZATION ERROR RATE

Out of the total 19-task prioritization challenges presented in each flight scenario, the number of errors committed was divided by the total, giving the error rate for each group for the pre-training and post-training flights. The error rate data can be seen in Table 5.1.

Table 5.1: Group and Flight Error Rates

	Pre Training	Post Training	Mean
Control Group	.21	.19	.20
Descriptive Group	.48	.26	.37
Prescriptive Group	.67	.35	.50
Mean	.45	.26	

ANOVA Analysis

To analyze the data, the experimenter used a 2 X 3 mixed ANOVA design, with flight (pre-training and post-training) treated as a within-subject variable and group (control, descriptive, prescriptive) treated as a between-subject variable. Table 5.2 presents the ANOVA analysis for error rate.

Table 5.2: ANOVA results of Task Prioritization Error Rates

Effect	df	SS	df	MS	F-ratio	p-value
Group	2	.1914125	9	.0799194	2.395	.147
Flight	1	.2053500	9	.0088806	23.123	.001
Group x Flight	2	.0429125	9	.0088806	4.832	.038

In this study, in order to determine whether a factor had a statistically significant effect, the experimenter used a p-value of less than 0.05 (i.e., a confidence level of 95%). The smaller the p-value, the more significant effect that factor had, and the more likely to reject the null hypothesis.

Main Effect of Group

Table 5.2 shows no significant main effect for group. Although it appears that the control group had a lower overall error rate (Figure 5.1), the main effect of group was not significant (p-value = .147).

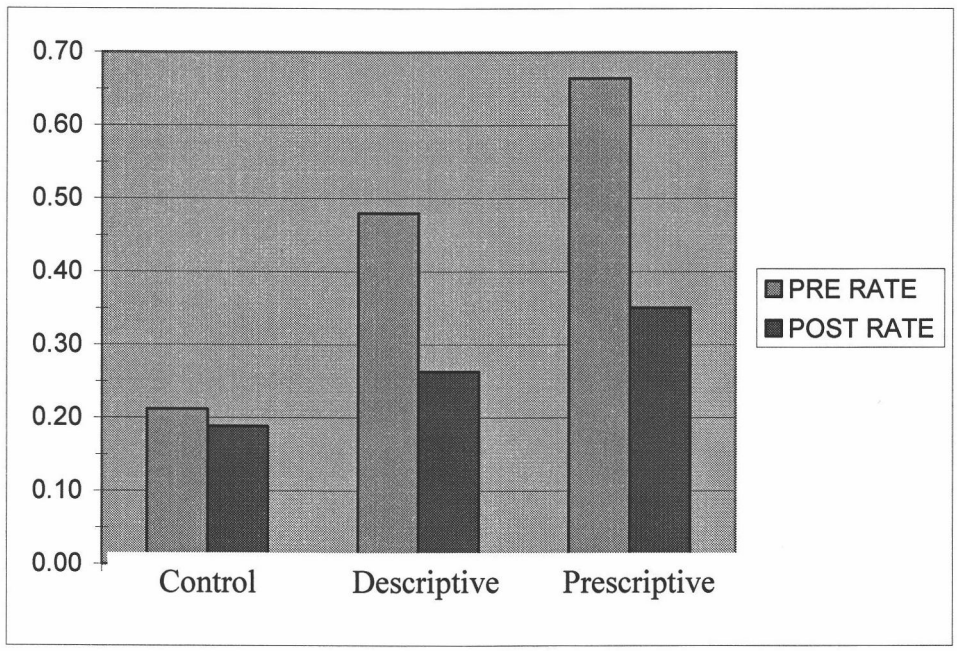

Figure 5.1: Error Rates Between Group and Flight

Main Effect of Pre-Training and Post-Training Flights

Table 5.2 shows a significant flight main effect. This main effect of overall error rate (Figure 5.2) between the pre-training and post-training flights was significant at a p-value = .001.

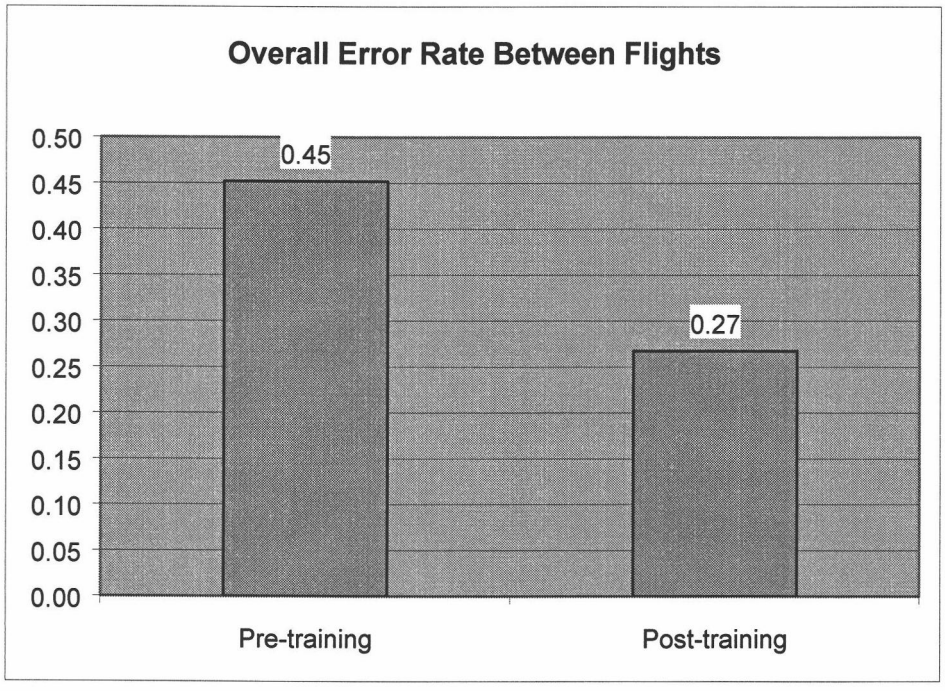

Figure 5.2: Flight Error Rate

This difference was expected between the pre-training and post-training flights and may be due to some practice effect, although the significance of the results suggests that the difference in error rate was beyond the practice effect.

Interaction Between Group and Flight

As shown in Table 5.2, an interaction effect was significant (p-value = .038). The error rates between pre-training and post-training flights depended on the group factor. Figure 5.3 shows the interaction plot representing group and flight error rates, and one can clearly see an interaction shown by the non-parallel lines.

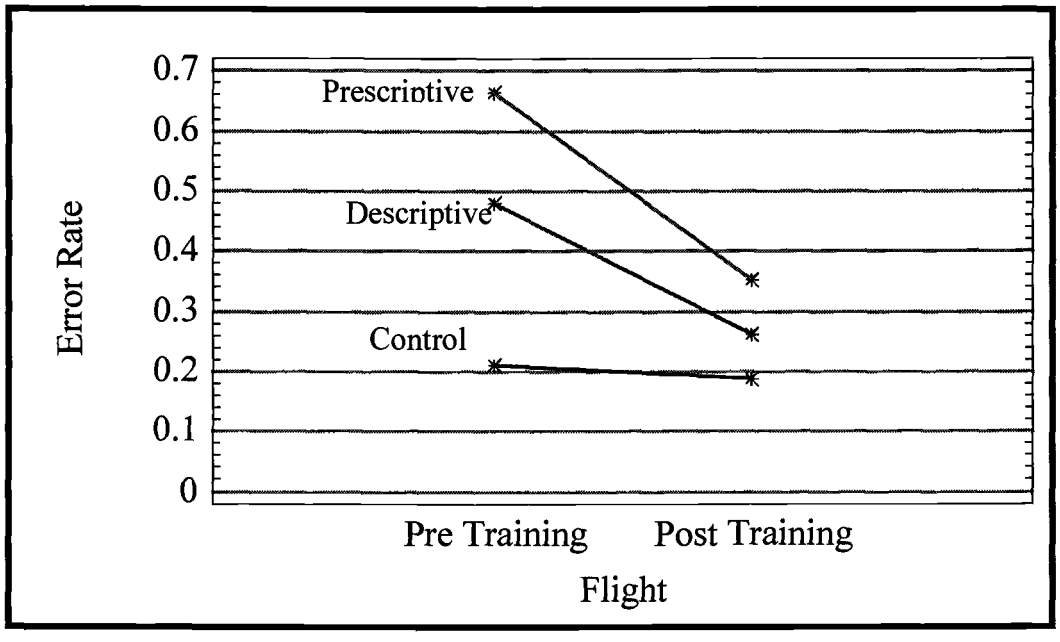

Figure 5.3: Interaction Plot of Group Level and Flight

The interaction suggests that the task prioritization error rate within the pre-training and post-training flight scenario depends on group. Figure 5.3 shows the prescriptive and descriptive group's decreasing error rate in the post-training flight.

Post Hoc Tests

The significant interaction was investigated by running follow-up analyses of simple interactions between groups. Post hoc comparisons focused on 2 (group) X 2 (pre-training, post training) ANOVAs, comparing two groups at a time. This method determined which groups were significantly different from one another with respect to the change in Task Prioritization error rate. The post hoc tests showed that:

1. The difference between Control group and Descriptive group was marginally significant at a p-value = .0714
2. The difference between Control group and Prescriptive group was significant at a p-value = .0137
3. The difference between Descriptive group and Prescriptive group was not significant at a p-value = .3387

A significant effect for this study at a p-value = 0.05 would lead us to conclude a significant difference between control group and the prescriptive group (p-value = .0137). Therefore, we can say that CTM training affected task prioritization performance error rate significantly for the Prescriptive group as compared to the control group (no CTM training). The marginally significant effect between the Descriptive group and Control group (p-value = .071) suggests that the descriptive group were also facilitated. With the significant interaction results and post hoc comparisons, the CTM prescriptive training proves to have an effect on task prioritization performance as compared to control group.

RESOLUTION RATE

Out of the total six malfunction challenges within each flight scenario, the number of malfunctions resolved was divided by six to give a resolution rate for the pre-training and post-training flights. The data can be seen in Table 5.3.

Table 5.3: Group and Flight Resolution Rates

	Pre Training	Post Training	Mean
Control Group	.75	.83	.79
Descriptive Group	.88	.96	.92
Prescriptive Group	.69	.96	.82
Mean	.77	.91	

ANOVA Analysis

To analyze the data, the experimenter used a 2 X 3 mixed ANOVA design, with flight (pre-training and post-training) treated as a within-subject variable and group (control, descriptive, prescriptive) treated as a between-subject variable. Table 5.4 presents the results of ANOVA analysis for the resolution rates.

Table 5.4: ANOVA results of Resolution Rates

Effect	df	SS	df	MS	F-ratio	p-value
Group	2	.034	9	.129	.262	.776
Flight	1	.125	9	.015	8.580	.017
Group x Flight	2	.023	9	.015	1.570	.260

Main Effect of Group

Table 5.4 shows no significant main effect for group. The group main effect of overall resolution rate (Figure 5.4) was not significant at a p-value = .78 with higher resolution rates during the post-training flight.

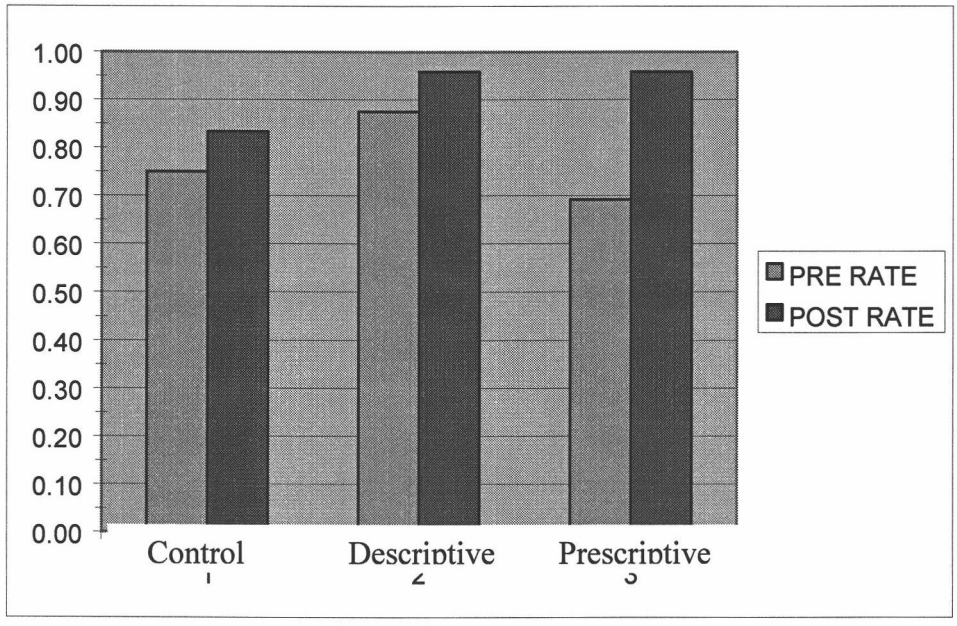

Figure 5.4: Resolution Rates

Main Effect of Flight

Table 5.4 shows a significant effect for flight. The overall error rate difference from pre-training to post-training (Figure 5.5) was significant at a p-value = .017.

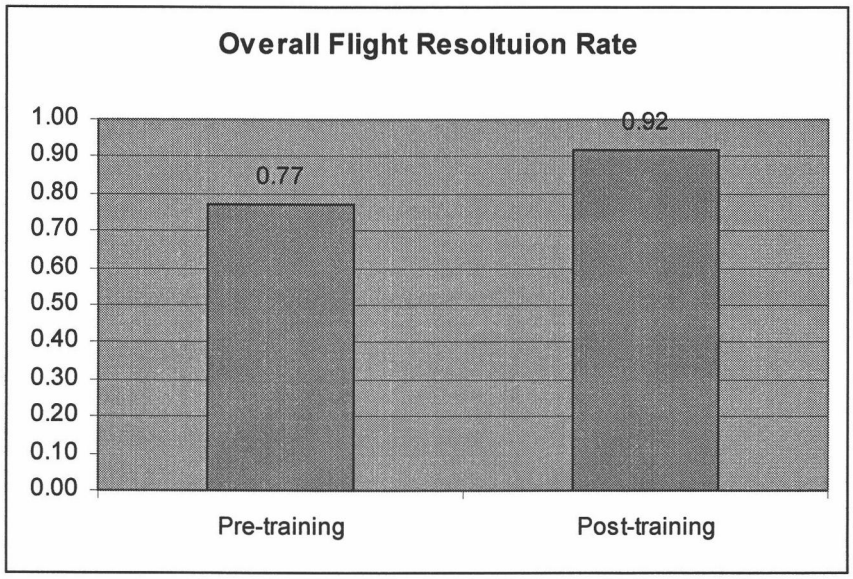

Figure 5.5: Overall Flight Resolution Rate

A difference is expected between the pre-training and post-training flights due to practice effect.

Interaction Between Group and Flight

As shown in Table 5.2, an interaction effect was not significant (p-value = .260). The resolution rates between pre-training and post-training flights did not depend on the group factor. Figure 5.6 shows the interaction plot representing group and flight resolution rates.

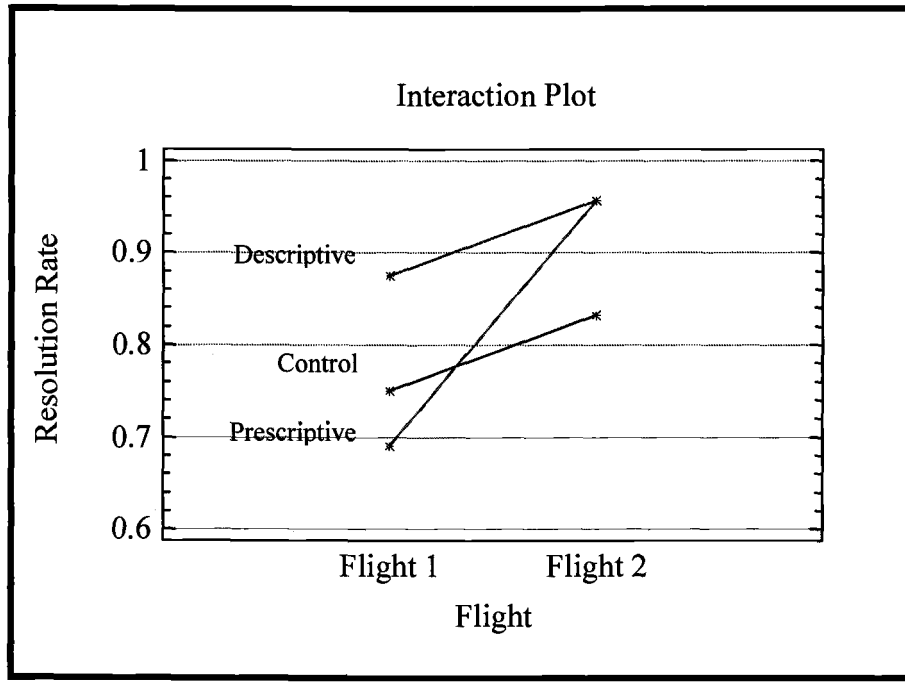

Figure 5.6: Interaction Plot of Group Level and Flight

The fact that the results showed no significant interaction suggests that the resolution rate between the pre-training and post-training flights was not dependent on training (the improvement is in the right direction, so a larger sample may reveal a significant effect).

MEMORY RECALL RATE

The ATC requested a total of five memory tasks. The number of tasks recalled is divided by the total number to give the recall rate for each scenario. The data can be seen in Table 5.5.

Table 5.5: Group and Flight Recall Rates

	Pre Training	Post Training	Mean
Control Group	.80	.68	.74
Descriptive Group	.70	.95	.83
Prescriptive Group	.58	.89	.73
Mean	.69	.84	

ANOVA Analysis

A 2 X 3 mixed ANOVA design, with flight (pre training and post-training) treated as a within-subject variable and group (control, descriptive, prescriptive) treated as a between-subject variable to analyze the data. Table 5.6 presents the ANOVA analysis for the results of the error rates.

Table 5.6: ANOVA Table of Recall Rate

Effect	df	SS	df	MS	F-ratio	p-value
Group	2	.017	9	.028	.603	.568
Flight	1	.074	9	.034	2.181	.174
Group x Flight	2	.171	9	.034	5.055	.034

Main Effect of Group

Table 5.6 shows no significant main effect for group with a p-value = .568. Figure 5.7 shows a plot of each groups recall rate during the pre-training and post-training flights.

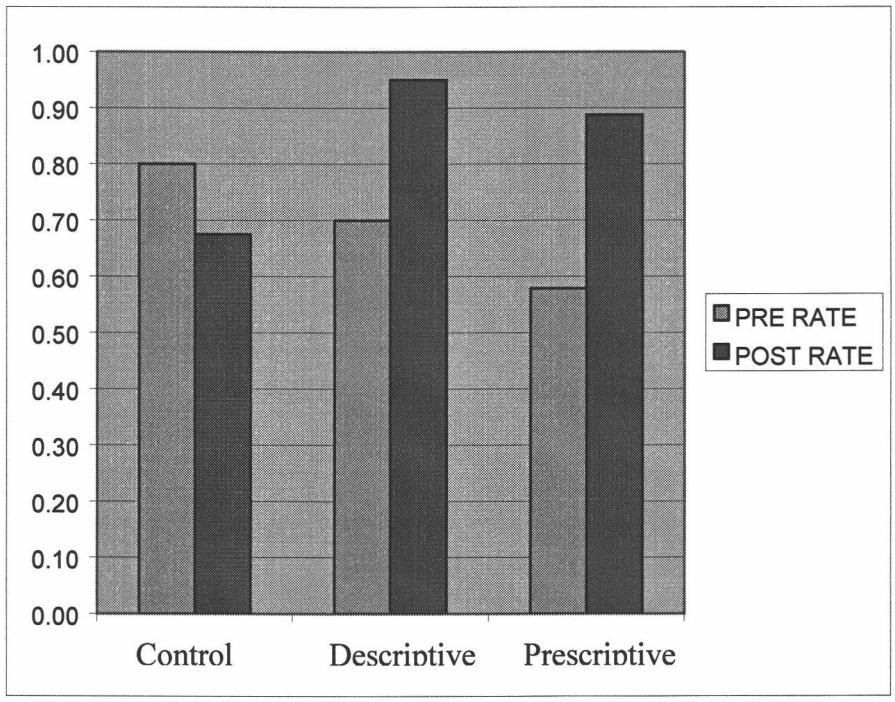

Figure 5.7: Recall Rates Between Group and Flight

Main Effect of Flight

Table 5.6 shows a non-significant effect for flight. The main effect of overall memory recall differences in the pre-training and post-training flights was not significant at a p-value = .17 (Figure 5.8).

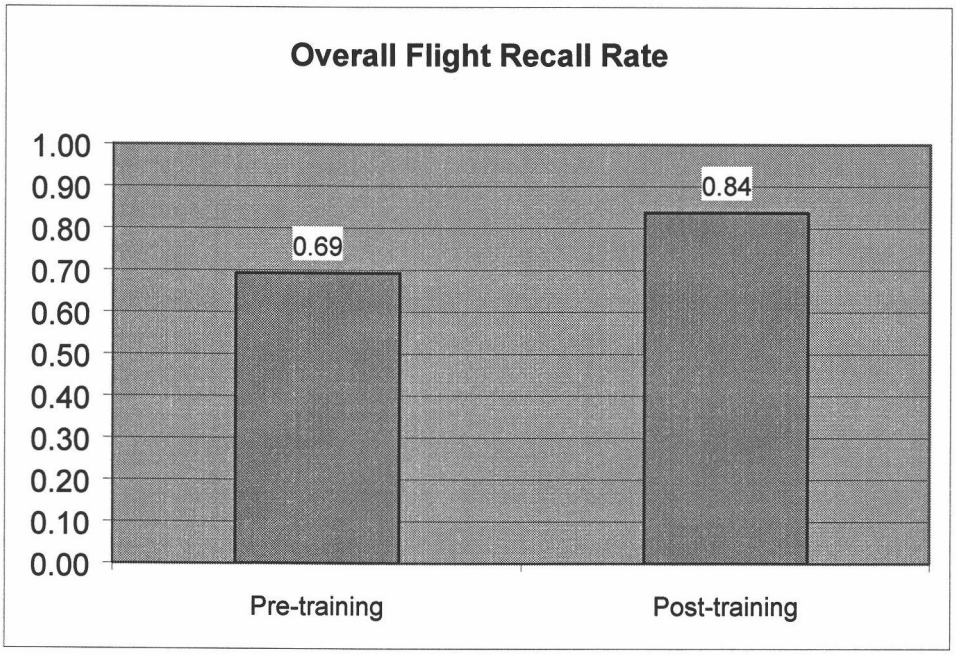

Figure 5.8: Overall Flight Recall Rate

The difference was expected between the pre-training and post-training flights due to a practice effect. However, the significant interaction effect, found in the results, suggests that an improvement in recall rate was dependent on training.

Interaction Between Group and Flight

As shown in Table 5.6, an interaction effect was significant (p-value = .034). The recall rate improvement between pre-training and post-training flights depends on the group factor. Figure 5.9 shows the interaction plot representing group and flight recall rates, and one can clearly see an interaction shown by the non-parallel lines.

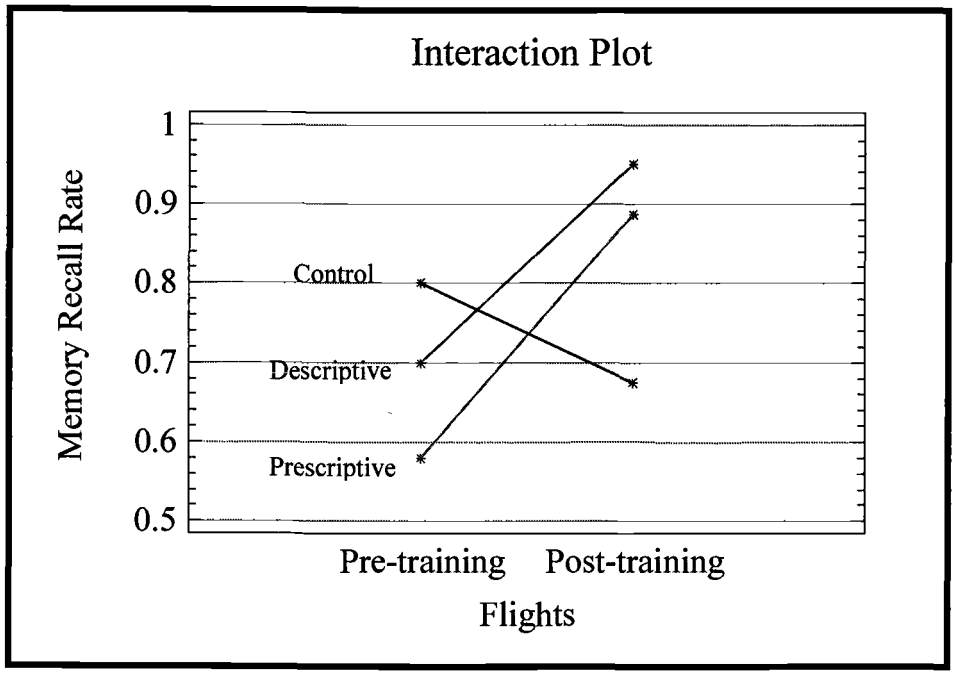

Figure 5.9: Interaction Plot of Group Level and Flight

The interaction suggests that the memory recall rate difference between the pre-training and post-training flights depends on group. We can see that the prescriptive and descriptive groups seem to have improved and that the control group did not improve between the two flights.

Post Hoc Tests

The source of the significant interaction was investigated by running follow-up analyses of simple interactions. Post hoc comparisons focused on 2(group) X 2 (pre-training, post training) ANOVAs comparing two groups at a

time. This method determined which groups were significantly different from one to another. The post hoc tests show that,

1. The comparison between Control group and Descriptive group was significant at a p-value = .029.
2. The comparison between Control group and Prescriptive group was significant at a p-value = .017.
3. The comparison between Descriptive group and Prescriptive group was not significant at a p-value = .762.

A significant effect for this study at a p-value = 0.05 would lead us to conclude a significant difference between the Control group and the Descriptive and Prescriptive groups. Therefore, we can say that CTM training improved memory recall rate performance significantly for the Descriptive and Prescriptive training groups as compared to the control group (no CTM training). Figure 5.9 indicates these findings, as the slopes of the training groups were steeper and improving as compared to the Control group. With the significant interaction results and post hoc comparisons, the CTM training facilitates memory recall as compared to no training.

PAIRWISE COMPARISONS FOR INDIVIDUAL GROUPS

The individual groups were assessed to determine significant differences from pre-training and post-training performance. These are pairwise comparisons of pre/post effects for each group. They were computed through simple effects ANOVA analysis. This controls for the effects on alpha level that would have arisen from multiple t-tests. The analysis was conducted in Statistica for each of dependent measures (error rate, resolution rate, recall rate) with significance at p-value of 0.05. Table 5.7 presents the paired t-test analysis results (t-values and p-values) for each dependent measure.

Table 5.7: Pairwise Comparison Results for each Dependent Measure

Error Rate	F-Value	P-Value
Control Group	.141	.716
Descriptive Group	10.654	.010
Prescriptive Group	21.993	.001
Resolution Rate		
Control Group	.937	.358
Descriptive Group	.940	.358
Prescriptive Group	.143	.012
Recall Rate		
Control Group	2.997	.117
Descriptive Group	3.699	.087
Prescriptive Group	5.587	.042

In general, one sees that the pre- and post-training simple effects ANOVA analysis shows significance (p-value $\leq .05$) of the prescriptive group across all dependant measures. The descriptive group shows significance in pre- and post-training only for error rate. The control group shows no significant improvements in all categories between the pre- and post-training flights.

POST-EXPERIMENT QUESTIONNAIRE

Participants took a post-experiment questionnaire to provide insight into their views about the experimental session as well as characteristics that might differ between participants. Participants varied in total flight hours (from 250 to

3000 hours), and ratings held, from single engine IFR to ATP (air transport pilot). Participants were flight instructors, commuter pilots, and recreational pilots.

All participants felt that they received adequate simulator training before flying the flight scenarios. The training familiarized participants with the flight simulator's behavior, and provided examples of system malfunction tasks. Additionally, all participants commented that both flight scenarios were equivalent in difficulty, and that no one scenario was any harder than another. Some participants commented that flying the IFR scenarios was more difficult than a real IFR flight due to simulator sensitivities and difficulty in maintaining altitude control. Some participants commented that maintaining altitude consumed the most attention, and that the sensitivity of controls was different than a real aircraft. In general, however, the comments regarding overall simulator behavior and aircraft characteristics were of a positive nature.

Participants in the training groups (descriptive and prescriptive) gave positive feedback on the training content, and all identified the importance of the CTM lecture material. Within the prescriptive group, learning the APE technique was relatively easy, although talking out loud, for some participants, required more practice time.

Participants additionally reported their own techniques to remember tasks within the cockpit. Many participants reported using techniques such as "GUMPs" (Gas-Undercarriage-Mixture-Prop) during an approach and landing phase. They reported using checklists to remember tasks in the cockpit.

ADDITIONAL ANALYSIS

It was interesting to see on Figure 5.3 that the control group error rate was quite a bit lower than the descriptive and prescriptive groups. Although the group main effect in error rate was not significant, running additional analysis on

potential confounding variables (MSFS experience and flight scenario order) may help explain the results. Figure 5.10 shows an error rate plot for each participant. Looking at the plot, each line is coded by the participant's identifier (ID). The ID 1PVA, for example, represents the participant number (1), group assignment (Prescriptive), and flight scenario order (Victor/Alpha). Arrows pointing to the five participants indicate MSFS experience.

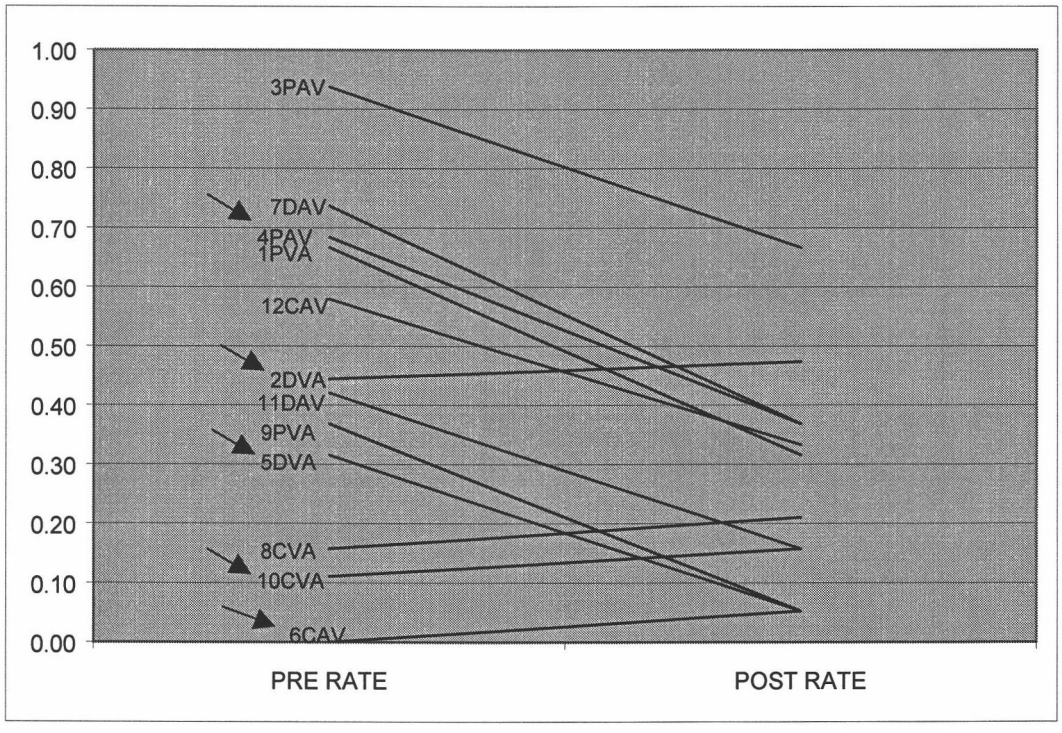

Figure 5.10: Individual Participant Error Rate

MSFS Flight Experience

One of the primary objectives for additional analysis was to find an interaction effect of flight simulator experiences on error rate. As can be seen in Figure 5.10, two control group participants with MSFS experience had the lowest error rates, and an additional control group participant with no MSFS experience had similar error rate performance.

ANOVA results show no significant interaction between MSFS experience and error rate (F-value = .502, p-value = .495). Therefore, MSFS experience had no significant effect on the error rate between pre-training and post-training flights.

Flight Scenario Order

The next objective was to analyze the order effects of flights to see whether flying the Alpha scenario or the Victor scenario as the pre-training flight caused any significant difference in error rate. Figure 5.11 shows the error rates for each scenario order.

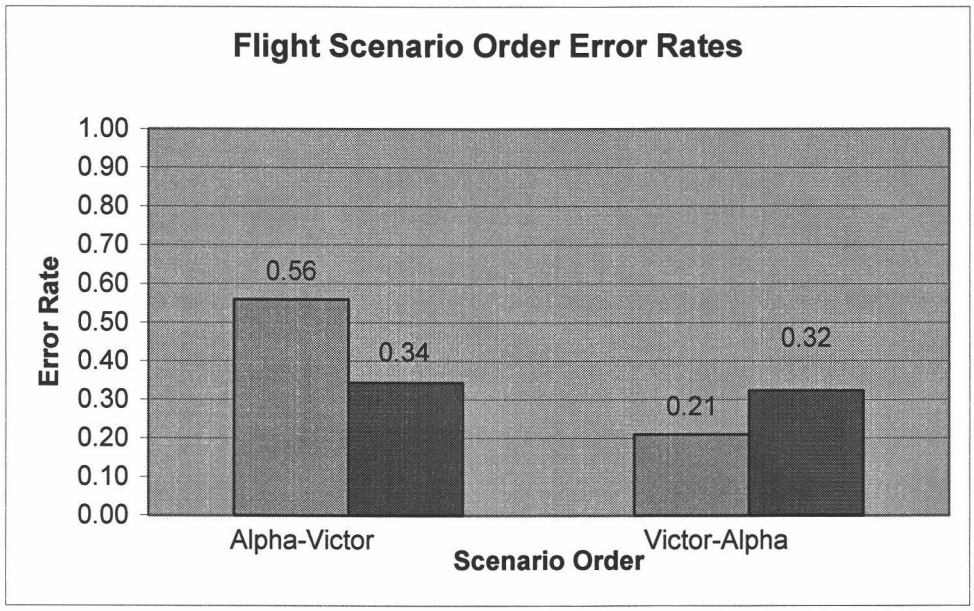

Figure 5.11: Error Rate for Post-training Flights

ANOVA results show no significant interaction between flight scenario order and error rate (F-value = 1.07, p-value = .325). Therefore, difference in flight scenario order, Alpha-Victor and Victor-Alpha order had no significant effect on error rate.

GENERAL SUMMARY

The results of this study suggest a rejection of the null hypothesis, "CTM training does not improve task prioritization performance". ANOVA results show a significant interaction effect (F-value = 4.832, p-value = .038) on group (control, descriptive, prescriptive) and flight (pre-training, post-training) on error rate

improvement. Post hoc comparison tests show significant differences between the control group and prescriptive group error rate improvements, implying training effects.

ANOVA results show no significant interaction on resolution rate (F-value = 1.570, p-value = .260) performance. This suggests that CTM training did not have an effect on improving resolution rate performance.

ANOVA results show a significant interaction (F-value = 5.056, p-value = .034) on memory recall rate. Post hoc comparison tests showed differences between the control group and both the descriptive and prescriptive groups, implying that CTM training improved recall performance. The descriptive and prescriptive training formats facilitated recall performance.

Additionally, pair-wise comparisons tests show the prescriptive group significantly improved across all dependent measures (error rate, resolution rate, recall rate), further confirming the effectiveness of CTM prescriptive training.

CHAPTER 5: DISCUSSION

This chapter presents a discussion of the findings in this study. Also discussed are the interpretations of the results, and factors that might contribute to the findings.

FINDINGS

The current study assessed the effectiveness of CTM training on task prioritization performance. First, the results indicate that participants in the descriptive and prescriptive training groups made fewer task prioritization errors on the post-training flight, but the control group did not improve. The prescriptive training group reduced task prioritization error rate beyond a practice effect as compared to the control group. The descriptive training group reduced error rate marginally.

Second, CTM training did not have a significant effect on improving malfunction resolution performance.

Third, results indicate that participants in the descriptive and prescriptive CTM training groups improved memory recall on the post-training flight. The descriptive and prescriptive group increased memory recall as compared to the control group. This indicates that both training methods facilitated recall rate.

Simple pairwise comparisons for the individual groups indicated that the prescriptive group significantly reduced error rate, while increasing resolution rate and recall rate from the pre-training to post-training flights.

Discussion of the interpretation for each of the findings is presented below.

ERROR RATE

The main objective of this study was to determine CTM training effectiveness on task prioritization performance. Two interpretations can be offered.

One interpretation is that CTM training improved task prioritization performance. More specifically, participants receiving the prescriptive training technique improved task prioritization performance. Therefore, the difference in error rate improvement, which this research sought to analyze, was due to training, not to a practice effect. The significant results indicate that the improvements in pre- to post-training flights was due to the training.

The alternative interpretation would be that CTM training does not improve task prioritization performance. Because of the initial low error rate of the control group in the pre-training flight, one might suggest that a floor effect exists. This effect would cause the control group to not improve any more that they did in the post-training flight because they were already very low. Therefore, the error rate improvements in the training groups were due only to a practice effect and not the training effect. Additionally, the descriptive and prescriptive post-training error rates did not decrease below the control groups. This suggests that the descriptive and prescriptive groups which performed more poorly on the simulator could not improve beyond the better-performing control group. One can state that the initial better-performing individuals have little room to improve, as compared to poorer-performing individuals who have more room to reach the better-performing control group's post-training error rate.

Although more research is needed, data results are more consistent with the first interpretation for the following reasons:

1. There was not really a floor effect. We can see that one participant in the control group had a zero error rate which shows the possibility of achieving an

error rate below 18%. Additionally, other participants were able to achieve an error rate below 18% during the pre-training flight.

2. There was no effect due to simulator experience. It was suggested that MSFS experience within the control group might have caused the initial low error rate. This was tested and did not have an effect on error rate.
3. The CTM training worked in improving memory recall rate as was expected. The control group recall rate decreased in performance in the post-training flight, while the training groups improved. These results show additional evidence of CTM training effectiveness.
4. The initial low error rate may have been due solely to a random chance event that the better simulator-performing participants were assigned to the control group.

In addition to the reasons listed, the individual group t-test comparisons showed the prescriptive training group improved in error rate, resolution rate, and recall rate. The descriptive training group improved in error rate performance. The control group did not significantly improve in reduction of error rate, resolution rate, or recall rate. These tests would also support the first interpretation.

This research favors the first interpretation: that CTM training improved task prioritization performance.

RESOLUTION RATE

The CTM training did not show an effect on resolution rate performance between the groups. The differences between receiving and not receiving training did not differ in resolution rate performance. The CTM training, descriptive or prescriptive, did not improve resolution rate performance in the post-training flight.

Reasons may be due to not having enough malfunction challenges within each flight to show a training effect. Additionally, the aircraft system malfunctions

may not have been complex enough, or limited in scope and thus not representative of all possible aircraft malfunctions. If more complex and intricate system malfunctions were developed and introduced to participants, this could show different CTM training effectiveness results. Additionally, the results were shown to change in the expected direction, so the non-significance of the interaction may have been due to not having enough participants.

RECALL RATE

The results for the recall rate performance showed the effectiveness of both CTM training groups. The recall rate for the control group decreased in post-training flight, while the descriptive and prescriptive groups increased in recall performance. The descriptive and prescriptive groups were significantly different in recall rate improvements as compared to the control group. Since there appears to be a significant difference between the descriptive and the prescriptive groups, this suggests that the CTM training in general improved recall performance.

PAIRWISE COMPARISON TESTS

It can be seen, from the pairwise comparisons performed on the individual groups, that the prescriptive group significantly improved across all dependent measures (error rate, resolution rate, recall rate). This would further indicate the advantages of prescriptive training techniques. Using the prescriptive training technique appears to provide more facilitation to participants than the descriptive training, because most pilots are familiar with memory techniques used in the cockpit to remember flight tasks.

STUDY LIMITATIONS

There may have been some limitations in this research that may have confounded the results. The flight simulator may have affected participant performance because it was static, motionless and low-fidelity. Additionally, the lack of tactile sensations to change aircraft systems, such as communication and navigation frequencies, and the VOR bearing track, added to limitations of the simulator. The control of the mouse button to change these systems is very different from touching the control on a real aircraft. In a true flight experience, the pilot would also have aural and tactile feedback for manipulating systems, whereas participants in the simulator were required to look at the control to make adjustments. In the simulator, all knobs and controls for the aircraft systems were virtual displays, and required pointing the mouse on the system to adjust, whereas in a real cockpit, some controls do not need to be looked at to change. Therefore, these limitations could have reduced participants' actual performance and confounded the results of the research.

The small sample of participants used in the study may have affected the results. A larger sample size in each group could provide a normal distribution of participant differences and normalize the initial pre-training performance. Additionally, more experience on the flight simulator may have normalized initial error rate and individual difference in flight simulator performance.

Experimental factors, such as classifying task prioritization error rates, were limited to the Aviate-Navigate-Communicate-Manage Systems hierarchy, which may have restricted the results for this study. Additionally, the task prioritization errors were only recorded at CTM challenge points, disregarding other errors committed during the flight. If errors committed throughout the flights were recorded, this might have affected the results shown in the study.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The study found some important interactions within the results. First, pre- and post-training error rate changed significantly depending on the group (control, descriptive, prescriptive)." CTM prescriptive training reduced task prioritization error rate from pre-training to post-training flights.

Second, post-training recall rate performance was significantly dependent on group. The descriptive and prescriptive training both increased recall rate in the post-training flight. CTM training in general, not type of training, improved memory recall performance.

Third, the prescriptive training group showed significant reductions in error rate, and improvements in resolution rate and recall rate between the pre-training and post-training flight means. The prescriptive training technique appeared to be effective in overall performance improvement from pre-training to post-training flights.

In summary, there is strong support for the hypothesis that prescriptive training reduces task prioritization errors. There is support for the hypothesis that CTM prescriptive training facilitates memory tasks. However, there was no evidence to support the hypothesis that prescriptive training improves malfunction resolution rate. In addition, the results show that CTM descriptive training marginally reduced task prioritization errors, and facilitated memory tasks.

RECOMMENDATIONS

Listed below are recommendations for future research.

1. Further research should be conducted to find a residual effect of training. This would test the training effectiveness on a long-term basis. Because the post-training flight followed immediately after training, the training information was still fresh in the participants' memory.
2. It is a conclusion of this research that CTM training improved task prioritization performance as compared no training. No strong conclusions can be made about the effectiveness of type of training. A next stage for this research would be to further investigate the effectiveness of type of training, distinguishing effectiveness of the prescriptive training. As reported in the post-experiment questionnaire, most participants use mnemonic techniques to remember tasks in the cockpit. Therefore, the prescriptive APE procedure has some practical functionality for participants.
3. The study was conducted using a low-fidelity flight simulator and it is not certain that these results will match real flying performance. It would be advantageous to represent more realistic flight in a full flight simulator.
4. A larger sample size would benefit further research by equalizing group randomization, identifying differences in resolution rate performance, and producing similarity in pre-training performance.
5. Future research may try to create more malfunction challenges in order to see an effect of CTM training on resolution rate.
6. Expanded research might provide simulator experience to participants until pre-training performance is normalized. Therefore, the initial performance of participants would be similar.
7. Future research can control for MSFS experience in participants recruited, and therefore accept only participants with or without experience.

FINAL COMMENTS

This study was a preliminary investigation into CTM training effectiveness on task prioritization performance. The analyses showed that 2 out of 3 dependent measures (error rate and recall rate) improved in performance due to CTM training.

By providing CTM training to pilots, and introducing the APE procedure to facilitate task prioritization performance, a long overdue integration of CTM awareness with current pilot training programs could develop.

The results of this study are encouraging in that task prioritization performance as a skill can be improved through the CTM training techniques developed in this research. If implemented in current pilot training programs, task prioritization, important to flight safety, can be improved. Tragedies such as that of Flight 401 could potentially be averted.

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APPENDICES

APPENDIX 1: CTM Flyer

Volunteer Pilots Needed for Human Factors Research

Pilots are needed to participate in a study of pilot behavior during a part task simulator flight. The study will be conducted on one day, and last approximately 5 hours.

Participants need to hold at least a single engine land, instrument flight rating, and at least 100 hours "pilot in command" total time.

The study will be conducted at Oregon State University department of Industrial and Manufacturing Engineering from January 2002 through February 2002.

This study is part of a thesis project in aviation human factors. Your participation is greatly appreciated to help conduct this study, and promote aviation safety.

For more information and to schedule a session, please call the number below or email.

Thank You.

Saher Bishara
Phone: (541) 737-5240 Office
(541) 713-7587 Evening
E-mail: *bishara@engr.orst.edu*

APPENDIX 2: Informed Consent Form

Oregon State University

Department of Industrial and Manufacturing Engineering

INFORMED CONSENT DOCUMENT

I agree to participate in research conducted by Saher Bishara under the supervision of Dr. Ken Funk of the Oregon State University department of Industrial and Manufacturing Engineering. After approximately 2 hours of introduction, training, practice, and gaining familiarization with equipment, I will be asked to fly 60-minute flight missions in a part-task flight simulator before and after training provided by the researcher. Afterwards, I will be asked to answer a brief questionnaire. The total length of the experiment should not be more than 6 hours in length.

I understand that my participation could cause me only minimal risk, inconvenience, or discomfort. That is, I understand that the probability and magnitude of harm, inconvenience or discomfort anticipated in this study are not greater than those encountered in daily life. I also understand that Oregon State University does not provide compensation or medical treatment in the event that I am injured or harmed in any way as a result of participation in this study.

I understand that all records collected in this survey are available to the research investigators, support staff, and any authorized research review committee. I grant Oregon State University permission to reproduce and publish all records, notes, or data collected from my participation, provided there will be **no association of my name** with the collected data and confidentiality is maintained unless specifically waived by me. I understand that I will not be paid for my voluntary participation in this survey.

I understand that I will have the opportunity to ask questions and receive satisfactory answers from Saher Bishara. I understand that any further questions concerning this survey should be directed to Dr. Ken Funk at (541) 737-2357.

If I have questions about my rights as a research participant, I understand that I should contact the IRB Coordinator, OSU Research Office, (541) 737- 3437.

My signature below indicates that I have read and that I understand the process described above and give my informed and voluntary consent to participate in this study. I understand that I will receive a signed copy of this consent form.

_____	_____
Signature	Date
_____	_____
Name	Contact Information

APPENDIX 3: Post-Experiment Questionnaire

Post-Training Questionnaire & Comments

Date: _____ Subject #: _____

1. Gender? M F

2. Age?

3. Did you have any experience using Microsoft flight simulator prior to this experiment?

4. Do you play any video games? If "Yes", what kind of games? How many hours per week?

5. How many flight hours, total time and instrument time, do you have?

6. What ratings do you hold? What aircraft to you most often fly?

7. Do you prefer to fly during the day or night?

8. How frequently do you fly?

9. Do you use any memory techniques or aids to help you remember tasks in the cockpit?
   If "Yes", what kind? Briefly explain.

10. What does Cockpit Task Management mean to you?

11. Do you have any comments or suggestions concerning this experiment?

Thank you for your participation

APPENDIX 4: CTM Lecture Content for Descriptive Group

Cockpit Task Management

Lecture material:

Lecture Outline:

I. Cockpit Task Management (CTM)

a. What is CTM

b. NTSB Accident Reports with Explanations

c. ASRS Incident Report with Explanations

d. What can I do about CTM errors

i. What to be aware of

Cockpit Task Management
{CTM}

Flying an aircraft requires the pilot to perform multiple, concurrent tasks, classified as

- Aviate tasks, those tasks concerned with control of the aircraft's motion;
- Navigate tasks, those tasks concerned with determining the present location and how to arrive at an intended location;
- Communicate tasks, those tasks concerned with transmitting information to or receiving information from another human, such as ATC; and
- Manage system tasks, those tasks concerned with the operating the aircraft's secondary equipment, such as its electrical system, hydraulic system, etc.

The cockpit is an environment in which potentially many important tasks simultaneously compete for pilot attention.

What is Cockpit Task Management?

Cockpit Task Management (CTM) is the process by which pilots selectively attend to flight tasks in such a way as to safely and effectively complete the flight.

CTM to a pilot means initiating tasks (such as ascending or descending to altitude), monitoring tasks (such as the vertical speed indicator), prioritization of tasks (Aviate vs. Communicate), execution of tasks (such as turning to heading during ATC vectors), and termination of tasks (suck as leveling off the plane). Most of these flight tasks happen at the same time, and the pilot must correctly choose which of the concurrent tasks he/she will attend to at any given time.

CTM has been categorized as a mental function that is inherently well understood by pilots and almost always performed satisfactorily (for example: Aviate, Navigate, Communicate, and Manage Systems hierarchy). However, there are many documented instances, such as Incident & Accident Reports, where tasks were not managed properly, resulting in an aircraft mishap.

To attend to a flight task, the pilot must allocate it attention, while at the same time, attention to other flight tasks decrease. Mental as well as physical (e.g., manual) effort must be given to the flight task so that information can be processed and (as appropriate), physical action can be taken to contribute toward achievement of the flight plan objectives.

- For example, monitoring the altimeter and the VSI. Once the pilot sees the VSI needle move to a positive rate of climb (attention to VSI), he/she can look at the altimeter to verify a positive rate of climb, the pilot will then

push the yoke forward (or adjust the trim) to level the aircraft back to the designated altitude (physical system).

In general, the pilot's capacity of available mental and physical resources is insufficient for all concurrent tasks to be performed simultaneously. In most cases, more tasks compete for the pilot's attention than can be attended to simultaneously. The pilot lacks the necessary eyes, hands, and mental capacity to do everything at once.

But under almost all operational conditions, all goals essential to a safe and effective flight can be achieved by selectively attending to and switching attention among flight tasks. Given that the aircraft is a reasonably stable platform, and due to the fact that many flight operations have been highly proceduralized and only require following procedures. It is not necessary to do everything at once. Tasks can be "pre-scheduled" in advance based on aircraft characteristics, environment, and airport terminal information, to achieve a safe and effective flight.

There are some tasks that most pilots can perform with little conscious attention. Such tasks include flying a properly trimmed aircraft straight and level in calm weather, or maintaining heading on course with calm air. They have been practiced so much, that they can be performed well automatically. On the other hand, there are those tasks that demand attention to perform, such as flying a difficult approach and maintaining attitude and heading in bad weather conditions, or diagnosing a malfunction. These controlled tasks require thought and conscious attention to conduct. It is possible for a pilot to carry on tasks performed "automatically", and tasks that require thought simultaneously. Pilots can perform multiple "automatic" tasks simultaneously. But it would be difficult to perform multiple "controlled" tasks simultaneously without facing difficulty or error.

Therefore CTM involves the prioritization of flight tasks, for attendance, based on their importance to flight safety (e.g., maintaining altitude vs. talking to a passenger), how urgent the tasks are (e.g., calling the final approach fix vs. calling an intersection during cruise), and how well the tasks are actually being performed (e.g., cleared to 5000, and your altitude is 5050 and stable vs. altitude at 5150 and climbing).

A task prioritization error occurs when the pilot does not give attention to a higher priority task – i.e., one more important to flight safety, one that is more urgent, or one that is currently not being performed at a satisfactory level – by attending to a lower priority task – i.e., one less critical to safety, one less urgent, or one that is already being performed quite well and is not in need of immediate attention.
In other words, proper task prioritization ensures the pilot is "doing what he should be doing at the moment."

- Suppose that ATC cleared an IFR flight to descend to 5,000 ft and the descent was in progress. Near the bottom of descent a fuse malfunction occurred. If the pilot corrected the fuse malfunction and in so doing undershot 5,000 ft ("busted" the altitude), a CTM task prioritization error has occurred.

By making pilots aware of the potential for task prioritization errors and of situations that have, in the past, led to accidents and incidents, we believe that the pilot's cockpit task management performance can be improved.

Examples:

{Note: **the following examples are taken from commercial aviation records, because these are what we have researched up to now. But the fundamental principles of CTM errors are relevant to general aviation.**}

1. On December 29th 1972, an Eastern Air Lines Lockheed L-1011 was on final approach when a nose landing gear position indication light illuminated. Following the missed approach because of a suspected nose gear malfunction, the aircraft climbed to 2,000 ft., leveled and proceeded on a westerly heading. The three flight crewmembers and a jumpseat occupant became engrossed in the malfunction.
Several minutes later, the aircraft descended into the ground 18.7 miles west-northwest of Miami International Airport. The aircraft was destroyed. Of the 176 people aboard, 101 received fatal injuries.
The National Transportation Safety Board determined that the probable cause of this accident was ***the failure of the flightcrew to monitor the flight instruments during the final 4 minutes of flight****, and to detect an unexpected descent soon enough to prevent impact with the ground (NTSB 1973).*
Explanation:

- In this example the higher priority task (Aviate) was more important because the pilot has to monitor, and maintain altitude in order to accomplish a safe flight. Therefore the plane does not descend in altitude and collide into terrain.
    - In this example the pilots judged the malfunction as a higher priority to safety than the Aviate task. Realistically the pilot could have "bought more time", and requested a hold over a fix while trying to solve the malfunction.
- The Aviate task, of monitoring and maintaining altitude, became more and more Urgent as the plane was losing altitude, the pilots did not identify this Urgency. The pilot perceived the malfunction as more Urgent to landing (task prioritization error), although the aircraft had enough fuel and time to circle, and postpone the landing in order to resolve the malfunction.

  - To an extreme, if the malfunction could not have been resolved, the plane could have landed on its belly without landing gear. This option is more favorable than the tragedy that resulted in this example.
- The status of both the Aviate task, and the Manage Systems tasks were unsatisfactory, although the Aviate task was deteriorating (high priority), and the Malfunction was stable (lower priority). This makes the deteriorating Aviate task the higher priority to allocate attention to perform. Therefore, due to poor situational awareness of not monitoring the Aviate task, and the pilot perceiving the malfunction as a higher priority for attendance, this resulted in a CTM error.

2. On February 11, 1981, a Lockheed JetStar crashed during an ILS approach to runway 16 at the Westchester County Airport, White Plains, New York. The area weather was dominated by low obscured ceilings, rain, fog, and reduced visibility. Winds were strong and gusty with moderate to severe turbulence in the lower levels. Following a recent malfunction of the generator control circuitry, the aircraft's electrical system had experienced several multiple generator failures. The National Transportation Safety board determined that the probable cause of this accident was a distraction to the pilot at a critical time as a result of a major electrical system malfunction which, in combination with the adverse weather environment, caused an undetected deviation of the aircraft's flightpath into the terrain. (NTSB, 1981).

Explanation:

- The Aviate task, monitoring and controlling the altitude and heading at this critical phase of flight is most important to safety. During the terminal stage of the flight, the Minimum descent altitude and timing is crucial to prioritize for the safety of the flight in order to avoid controlled flight into terrain. The distraction caused the pilot to divert his attention to another important task during flight. Although the electrical system was not serious enough to hinder the landing, the pilot aloud the malfunction to hinder his monitoring attention to the Aviate task.
- The Urgency between controlling the aircraft (high priority) vs. the electrical malfunction (lower priority) during the critical phase of flight was placed on the lower priority task. Therefore, the pilot allocated his attention solely on the malfunction, and disregarded monitoring the (higher priority) Aviate task.
- The status of the Aviate task became unsatisfactory by loss of monitoring during the malfunction. It became more and more crucial to attend to the Aviate task in order to bring it to a satisfactory level. Though the electrical malfunction status was unsatisfactory, it was stable, and less of a priority vs. the Aviate task deteriorating as time passed.

ASRS Incident Reports (pilot narratives):

3. We were cleared for the ILS approach and advised to contact the tower at the outer maker. At this time the crew became involved with checklists and inadvertently forgot to contact the tower prior to our landing.

Explanation:

- This example describes a Communicate task (contact tower) vs. Manage System task (complete checklists). The importance of the communicating task before landing is crucial during the terminal phase of flight. Other aircrafts may be in the vicinity during landing, and not contacting tower could lead to an in-flight collision. Although completing the checklist prior to landing is an important task to conduct, the pilot can delay the landing until the checklist is completed. In result, not only is the pilot safe, but other aircraft, as well, are free from harm.
- The Urgency of the checklist completion was high in order to perform before landing. And this made the checklist completion task vs. contacting tower a higher priority. The pilot apparently starting the checklist late in the flight phase, therefore increasing the Urgency to complete, and distracted the pilot from contacting tower.

4. Looking for traffic outside after TCAS II radar showed close traffic. We went through the cleared altitude of 9000 feet by 270 feet, and immediately climbed back up. "Always stabilize the aircraft before both heads are outside looking for traffic.

Explanation:

- The higher priority task, Aviate, was not attended to during the traffic watch. Monitoring the Aviate task is important so as not to bust a clearance altitude due to other aircraft flying in the vicinity. Clearance altitudes provide separation of aircrafts. By having the radar, the pilot could have diverted his flight path, or adjusted speed for the other traffic. Instead, the pilot allowed the lower priority, traffic watch, distract him from monitoring altitude the higher priority Aviate task.
- There is a greater Urgency to climb and maintain clearance altitude when given, so as not to affect other traffic. The Urgency to look for traffic is less important, and could have been resolved, by appropriate actions, without busting altitude.
- The status of the altitude was unsatisfactory and deteriorating due to attention allocated to the traffic watch. Distracted by the traffic watch, the pilot failed to stabilize, monitor, and control the Status of the higher priority Aviate task. If the Status of the traffic separation became unsatisfactory, the pilot could have requested deviation until satisfactory separation.

5. "..We had both failed to note the turn to the N. at TWIK intersection...All preoccupied by a cockpit distraction – Captain pushed the flight attendant button to pick up meal tray. No one responded and tray fell onto the floor. Captain picked up the mess and took it back to the galley and...I got real busy with several radio calls and altitude changes.

Explanation:

- The importance of Aviating/Navigating vs. clearing a meal tray is obvious in this example. Clearing the meal tray is of low importance, and could have been delayed until the aircraft was on the ground. Aviating/Navigating was more important because it can prevent the pilot from flying into dangerous areas, and maintain flight plan objectives. Clearly the pilot mis-prioritized the tasks in this example, and committed a CTM error.
- The urgency of Aviating and identifying the turn at the intersection becomes high as the intersection nears. The pilot committed a task prioritization error by attending to a less urgent task (clearing the meal tray) vs. navigating at the intersection as it approached.

6. "Departure requested verification of our altitude which was reported as "out of 7,800" for 8,000 ft.. We were then advised that we were only cleared to 6,000. The main factor contributing to this flight being at the wrong altitude was that the wrong altitude was set into the altitude reminder and not picked up by any of the crew members...Other factors involved: Our increasing dependence on the altitude reminder which gives no signal that you did not set in the proper altitude. Also being in VFR conditions, the crew was looking about for other aircraft rather than keeping their heads in the cockpit and being more aware of the altitude. (p. 16)

Explanation:

- Importance to the Aviate task is crucial when assigned an altitude to maintain with traffic in the area. The pilots, distracted by the traffic, failed to correctly input the correct altitude in the reminder window. During IFR separation, center can divert an aircrafts path to prevent in-flight conflicts. Failing to monitor the Aviate tasks, making it a low priority, led to not picking up the mistake earlier during the flight.
- The Urgency of maintaining and controlling altitude became more crucial as the aircraft busted the clearance altitude. Although the pilots failed to realize the Urgency of the altitude deviation, the reason was an over reliance on the altitude reminder window.
- The status of the high priority Aviate task was unsatisfactory and deteriorating, which led to the center calling to verify altitude clearance. Both tasks were unsatisfactory during the flight, but the Aviate tasks was deteriorating vs. Looking for traffic, which was stable. Maintaining the clearance altitude should have been a higher priority vs. looking for traffic, especially when the aircraft is monitored on radar by center.

7. "We were concentrating on the approach and missed the call to Tower.

Explanation:

- This example led to an unauthorized landing.
- Although Navigating (concentrating on the approach) is a more important task than Communicating (contacting tower), there is a point during the approach where contacting tower is part of the approach procedure. The importance during that point, contacting tower, is crucial for a safe landing. The pilots apparently forgot to call tower due to a high workload, and high attendance allocated to perform the approach.
- The Urgency to call tower at a designated point during the approach is crucial in order to maintain aircraft separation and safe landings. Throughout the approach, there are points of Urgency in the timing of the flight legs. But most nearly all approach procedures require contacting tower at fix's, which make the communicating task a priority to perform.

8. "...The Pilot not flying (PNF) was in the process of completing the approach checklist when clearance for the bay approach was given. The checklist was interrupted leaving an incorrect inbound course set in the ILS front course window. On this aircraft this well result in an improper capture of the localizer which occurred in this case."

Explanation:

- The Importance of completing a checklist, in order to properly configure the aircraft, is a high priority in order to land safely. Although clearance communication is an important task to perform, the crew mis-prioritized their tasks by not resuming checklist completion after clearance.
- After the clearance call was made, the Urgency to complete the checklist increased the further along they were in the approach. By not identifying the incomplete checklist, and its high Urgency before landing, the pilots committed a CTM error.
- During the approach, an improper capture of the localizer occurred, which made the Status of the Aviate task unsatisfactory as time passed. The pilots did not pick up the deteriorating status until the last minute, which caused problems in the landing. By prioritizing the Aviate vs. Communicate tasks, the pilots could have identified the problem earlier without causing an aircraft mishap.

<u>What Can I Do about CTM Errors?</u>

What to be aware of:

High Workload

- CTM errors are positively correlated with workload. The more flight tasks and the more difficult the tasks the pilot has, the better the chance of committing a CTM error.

- Multiple tasks, under high workload during flight results in resource limitation in the amount of tasks to attend and monitor at the same time.
    - Time and attentional resources are consumed in determining what to do next.

Non-Normal Situations

- Non-normal situations, such as malfunctions, and diagnosis of malfunctions (or dropped meal trays) degrade the pilots' ability to monitor other flight tasks.
- Stressful situations, decision-making, and malfunction diagnosis can cause "Cognitive Tunneling" of a pilot. This results in loss of situational awareness of flight tasks.
- Unexpected Revisions or Changes in procedures, approaches, and Nav/Comm frequencies can distract a pilot, and cause some confusion in flight tasks. This can lead a pilot to forget to start, complete, or monitor flight tasks.

Distractions / Interruptions

- Distractions prevent the pilot from doing what he should be doing, such as monitoring, or concentrating on flight task. Distraction can occur during flights from passengers, other traffic, ATC communication, and cockpit organization. These situations could cause memory lapses in forgetting flight tasks.
- Interruptions prevent the pilot from successfully completing flight tasks. So as the pilot is going through a landing checklist, a situation would interrupt the checklist completion. Such an interruption during checklist review, can hinder a pilot from checklist completion, and lead to distracting the pilot.

Critical Flight Phase

- Certain phases of flight where CTM becomes critical, such as the approach and landing phase, even slight misprioritizations of tasks, which are of little consequence during cruise flight, can have grave results.
    - Critical points in flight such as Approach and Landing, and Takeoff and Climb tend to cause the pilot to concentrate on a limited number of flight tasks.
- Time pressure's can cause pilot's to mis-manage flight tasks, such as allocating to much attention to a single task.

Poor Situational Awareness

- Limited knowledge of the present state of the aircraft, aircraft performance, and the environment may contribute to poor CTM performance.
- "Ego"

APPENDIX 5: APE Procedure

Cockpit Task Management

Lecture material:

Lecture Outline:

I. Cockpit Task Management (CTM)
   a. What is CTM
   b. NTSB Accident Reports with Explanations
   c. ASRS Incident Report with Explanations
   d. What can I do about CTM errors
      i. What to be aware of

{This section only applies to prescriptive group.}

II. A P E introduction:
   a. What is A P E
      i. Augmented checklist and decision making aid
   b. Why use A P E
      i. Promote Situational Awareness and Task Prioritization
   c. How to use A P E
      i. Talk out loud throughout A P E process
   d. When to use A P E
      i. During instrument scan, Comm., Malfuntions

A P E

Assess Prioritize Execute

By making pilots aware of Cockpit Task Management and the potential for task prioritization errors during a flight mission, the A P E will aid pilot decision-making in the cockpit, and improve Cockpit Task Management performance. *(Handout of A P E)*

What is A P E?

A P E can be considered as an augmented checklist and decision-making aid to the well known Aviate, Navigate, Communicate, and Manage Systems Hierarchy. Going through the A P E process, the pilot increases situational awareness in the cockpit, and increases task prioritization.

A P E is a simple and effective mnemonic tool that can be used by student pilots, intermediate pilot, and professional pilots to promote more efficient situational awareness of flight conditions and achieve goals towards a safer flight.

How to use A P E:

Throughout the A P E process, it is important to talk out loud. This will not only provide good memory recall of concurrent task to attend to, but also reinforce tasks completed, or uncompleted throughout the flight.

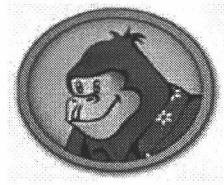
The picture of the A P E will also provide the pilot a memory recall to run through the A P E process throughout the flight.

When to use A P E:

The A P E process should be used as often as the pilot scans the instrument panel during flight. As a memory recall, the pilot should run through the A P E process each time the artificial horizon instrument is viewed.

To improve Cockpit Task Management, let the A P E help you.

A P E



Assess Prioritize Execute

Assess the situation: Aircraft systems, environment (internal/external), tasks and procedures. **"What's going on?" "What should I be doing?"**

Prioritize your tasks: **Aviate, Navigate, Communicate, Manage Systems, (ANCS).**

1. **Aviate**: Fly the aircraft, maintain heading, altitude, and speed, control the aircraft within operational limitations.
   - **"Is my aircraft in control? Right altitude, heading, and speed?"**
     - If "No", then Aviate is high priority.
     - If "Yes", then proceed.

2. **Navigate**: Know where the aircraft is and where you are going.
   - **"Do I know where I am, where I'm going, and how to get there?"**
     - If "No", then Navigate is high priority.
     - If "Yes", then proceed.

3. **Communicate**: with ATC, FSS, other Aircraft, etc. to receive or report necessary information.
   - **"Have I reported or received necessary information?"**
     - If "No", then Communicate is high priority.
     - If "Yes", then proceed.

4. **Manage Systems**: Monitor, operate, engine(s), electrical system, aircraft instruments, Nav/Comm equipment, etc. Manage cockpit.
   - **"Are my systems okay?"**
     - If "No", then Manage Systems is high priority.
     - If "Yes", then proceed.
     -

Execute the high priority tasks Now. Then reapply A P E.

Think out loud

APPENDIX 6: Random Generated Assignments

#	Random	Group	Scenario	ID
1	0.42	Prescriptive	VA	1PVA
2	0.22	Descriptive	VA	2DVA
3	0.15	Prescriptive	AV	3PAV
4	0.66	Prescriptive	AV	4PAV
5	0.73	Descriptive	VA	5DVA
6	0.96	Control	AV	6CAV
7	0.83	Descriptive	AV	7DAV
8	0.37	Control	VA	8CVA
9	0.32	Prescriptive	VA	9PVA
10	0.87	Control	VA	10CVA
11	0.97	Descriptive	AV	11DAV
12	0.38	Control	AV	12CAV

Randomly Generate Participant Group Assignment.

APPENDIX 7: CTM Challenge Checklists

<u>Burley to Twin Falls CTM challenges</u>: "Alpha"

1. Aviate vs. Communicate
   - @ 5080, pilot handed off to Dep.

Time:

2. Aviate vs. Communicate
   a. While climbing to altitude, Departure gives pilot dep. Instructions.

Time:

3. Aviate vs. Navigate Vs. Comm.
   - Flying towards Bur. VOR, pilot must Comm. Dep. Instructions

Time:

Memory Task: Report when established on the Victor-444 Radial. ("Yes")

4. Aviate vs. MS (Resolution: Yes No)
   - While tracking the VOR, MS task: Alt. Side OFF

Time:

5. Aviate vs. Navigate vs. Comm.
   - .6 miles from VOR pilot asked to switch frequency to Departure #2

Time:

6. Aviate vs. Navigate
   - While tracking the V-444 radial, pilot asked to climb to 7000.

Time:

7. Aviate vs.Comm.vs.MS (Resolution: Yes No)
   - @ 6980, pilot handed to Hailey approach. MS. Task: Fuel Pump ON

Time:

Memory Task: Report crossing Shone Intersection.("Yes")

8. Aviate vs.Comm.
   - @7980, pilot asked to report tops.

Time:

9. Aviate vs. Navigate vs. Comm.
   - Crossing "Shone" X-tion, pilot handed off to ATC #2.

Time:

10. Aviate vs. MS (Resolution: Yes No)
    - Transponder radar contact lost. Pilot asked to reset transponder.

Time:

11. Aviate vs.Comm.
    - Tracking VOR, pilot receives handoff to Twin Approach

Time:

12. Aviate vs. Comm.
    - Pilot is read ATIS for TWFS.

Time:

13. Aviate vs. Comm.
    - @ 7020, pilot handed off to Approach #2.

Time:

14. Aviate vs. MS (Resolution: Yes No)
    - @ 6520, MS task: Carb.heat "On/Off"

Time:

15. Aviate vs. Navigate
    - Pilot informed that Localizer out for ILS approach, and revised for VOR approach.

Time:

Memory Task: Report Crossing VOR. ("Yes")

16. Aviate vs. Comm. vs. Navigate:
    - .6 miles from VOR, pilot cleared for VOR approach. And pilot reports crossing VOR

Time:

Memory Task: Report procedure turn outbound.("Yes")

17. Aviate vs. MS *(Resolution: Yes No)*
    - MS task: Flaps 10 degrees retracted

Time:

18. Aviate vs. Navigate vs. Comm.
    - When establishing on VOR, pilot handed off to Tower

Time:

Memory Task: Report outer marker (or 3 miles out) ("Yes")

19. Aviate vs. MS *(Resolution: Yes No)*
    - MS task: Landing gear UP

Time:

<u>Twin Falls to Burley CTM challenges:</u> "Victor"

1. Aviate vs. MS (Resolution: Yes No)
   - During climb. MS task: Carb heat on.

Time:

2. Aviate vs. Communicate
   - @ 5980, pilot handed to departure

Time:
Memory Task: Report crossing VOR ("Yes")

3. Aviate vs. MS *(Resolution: Yes No)*
   - While tracking the VOR, MS task: Cowl Flaps.

Time:

4. Aviate vs. Navigate vs. Com
   - .6 miles fr. VOR, pilot handed off to Departure control.

   Time:
5. Aviate vs. Navigate
   - Crossing VOR pilot cleared to new altitude while establishing on Victor Airway.

   Time:
6. Aviate vs. Comm.
   - @ 7980, pilot handed off the Center

Time:
Memory Task: report crossing Ocley intersection
("Yes")

7. Aviate vs. Comm. vs. MS *(Resolution: Yes No)*
   - @ 8980, pilot asked to report distance from TWFS VOR. MS task: Master switch ALT side OFF.

   Time:

8. Aviate vs. MS *(Resolution: Yes No)*
   - MS task: radar contact lost, transponder frequency recycle, and set new code.

Time:

9. Aviate vs. MS *(Resolution: Yes No)*
   - @ 9520 MS task: Pitot Heat "On"/"Off".

Time:
10. Aviate vs. Navigate vs. Communicate

- Crossing X-tion, pilot handed off to Center #2

Time:

11. Aviate vs. Comm.
    a. @ 9020 pilot receives handoff to Hailey approach.
    Time:

12. Aviate vs. Comm.
    - Pilot receives ATIS for Burley airport

    Time:

13. Aviate vs. Comm.
    - @ 8020, pilot handed off to Burley approach.

Time:

14. Aviate vs. Navigate
    - Pilot given revision to approach, and must review new approach plate.

Time:

15. Aviate vs. Comm.
    - @ 7020, pilot handed off to Burley approach.

Time:
Memory Task: report crossing VOR ("Yes")

16. Aviate vs. Navigate vs. Comm.
    - Crossing VOR pilot must "Navigate radial, Report, and descend"

Time:
Memory Task: Report procedure turn inbound ("Yes")

17. Aviate vs. MS *(Resolution: Yes No)*
    - MS task: Landing gear UP (Prop)

Time:
18. Aviate vs. Navigate vs. Comm.
    - Establishing on VOR approach, pilot handed off to Tower.

    Time:

Memory Task: Report crossing VOR ("Yes")
19. Aviate vs. Navigate
    - @ 5520, descending to minimum approach altitude. Pilot reports distance from VOR.

    Time:

APPENDIX 8: Alpha Scenario Script

Tasks	Pilot	Controller	Events	Comments	Challenge
IFR Flight Plan	FSS: 789OS, C-182 slash Alpha, one three zero knots, Burley, 1530 Zulu, eight thousand feet, Victor-444 Shone, Twin Falls direct. Destination Twin Falls, one hour, five hours fuel, alternate Jerome, Name: John Doe, on file at Naviation, one on board, aircraft is Gold on White".	"Okay, have a good day		Verbally call out flight plan to pilot:	
Listen to ATIS	Tuned to ATIS frequency 135.55	ATIS: Burley Terminal, Airport information Delta, one seven zero zero Zulu weather. Indefinite ceiling five hundred, sky obscured, visibility one half, light rain and fog, temperature three four, dew point three two, wind on five zero at five, altimeter two niner niner two. VOR A runway Two in use, landing Runway Two Zero, Departing runway Two. Advise Burley Clearance on 124.6 you have information Delta".		Ask pilot to dial ATIS, when ready to copy; read out ATIS to pilot.	
Call Clearance Delivery: 124.6	"Burley Clearance, Skylane seven eight nine Bravo Victor, IFR to Twin Falls with Delta.	November seven eight nine Bravo Victor is cleared to the Twin Falls municipal airport via after departure Runway two, maintain runway			

	Repeat Clearance	heading, expect radar vectors to Victor 444 as filed. Climb and maintain five thousand one hundred, expect eight thousand one zero minutes after departure. Departure frequency will be one two five point three five (125.35). Squawk five two four seven (5247). "Cessna nine Bravo Victor, read back is correct, Have a good flight.		Pilot must remember instructions after takeoff	
Contact Ground 121.9	Ground control: "Burley Ground, skylane seven eight nine Bravo Victor at Naviation with Delta and clearance. Ready to taxi "Roger, Taxi to Runway Two. Tower on one one nine point seven.	"Cessna Nine Bravo Victor, taxi to runway Two. Wind is zero five zero at five, altimeter two niner niner two. Contact Burley Tower on one one nine point seven (119.7)			

Contact Tower: 119.7 Departure Time:	"Burley Tower, Cessna seven eight nine Bravo Victor is ready on Two. "Roger, position and hold on two "Nine Bravo Victor, cleared for takeoff.	"Cessna Nine Bravo Victor, taxi into position and hold, traffic landing runway two zero. "Cessna seven eight nine Bravo Victor, cleared for takeoff. "Cessna nine Bravo Victor Contact Burley departure now on one two five point three five (125.35). Have a good flight."	Plane enters clouds at 500ft. AGL	Time should be recorded at takeoff. After takeoff, and before reaching altitude by 50 ft. Pilot is requested to contact Departure.	
Record Time of: Comm: Response:	"Nine Bravo Victor, one two five point three five."		**@5080** msl. 20ft. before reaching 5100ft. altitude, pilot handed off to departure.		**1. Avigate (altitude) vs. Communicate (departure)**
Contact departure Time recorded: Comm: Response:	"Burley Departure, Cessna seven eight nine Bravo Victor is with you at five thousand one hundred.	"Cessna Nine Bravo Victor, Burley Departure, radar contact. Proceed direct to Burley VOR. Join Victor-444 on course to Shone, climb and maintain six thousand. Report		Pilot must maintain Aviation tasks while receiving ATC instructions.	**2. Aviate vs. Comm** **Memory Task**

	"Leaving five thousand, climbing six thousand, proceed to burley VOR, then Victor-444 to Shone, Report when established on the radial,	when established on the Victor-444 radial.		Pilot must remember to report when establish on the Victor-444 Radial. Pilot is now navigating towards Burley VOR.	**3. Aviate vs. Navigate vs. Comm**
Time of MS activation: Resolved: Yes/No			While tracking the VOR Manage systems Task, Master switch **Alt. Side off.** (F1)	Manage systems light will light, indicating a manage systems task	**4. Aviate vs. Manage Systems:**
Comm. time: Response:	"One two five point seven, Nine Bravo Victor, "Burley Departure, Cessna seven eight nine Bravo Victor is with you at six thousand	"Cessna Nine Bravo Victor, contact Burley Departure on one two five point seven (125.7).	**.6 miles** DME from Burley VOR pilot asked to switch frequency to Burley departure on one two five point seven five.		**5. Aviate vs. Navigate vs. Comm.**
Burley Departure #2:	"Leaving six thousand, climbing seven thousand, Nine Bravo Victor "Burley Departure, Cessna Nine Bravo Victor is establish on the Victor-444 Radail,	"Cessna nine Bravo Victor Roger, radar contact, climb and maintain seven thousand. "Roger, Nine Bravo Victor "Cessna Seven eight nine Bravo Victor, contact Hailey approach now, one two five			**6. Aviating (altitude) vs. Navigating (Victor-444)**

Comm: Response: Manage system: Resolution: Yes/No	"One two five point zero, Nine Bravo Victor.	point zero (125.0).	**@ 6980,** Burley Departure hands off to contact approach Manage systems Task: **Fuel Pump On (F2)**	Pilot will be challenged with leveling plane at desired altitude, communication, and a manage systems task.	**7. Aviate vs. Comm. vs. Manage System**

Hailey Approach:	"Hailey Approach, Cessna seven eight nine Bravo Victor is with you at seven thousand.				
	"Nine Bravo Victor, Ident. (Verbal callout)	"Cessna Nine Bravo Victor Hailey approach, Ident. Hailey Altimeter two niner niner four.			
	"Nine Bravo Victor, leaving seven thousand, climbing to eight thousand, report crossing Shone intersection,	"Cessna Nine Bravo Victor, radar contact. Climb and Maintain eight thousand. Report crossing Shone intersection.			**Memory Task**
Reporting Tops of	"Nine Bravo Victor,	"Cessan nine Bravo Victor, can you	**@7980** 20 ft. Before reaching		**8. Aviate**

clouds: Time of Comm: Time of MS: Resolution: Yes/No Comm: Response:	tops at 7800, "One three one point two five, nine Bravo Victor, and Nine Bravo Victor has just crossed Shone intersection,	report tops? "Cessna nine Bravo Victor, Thank you. "Cessna nine Bravo Victor, contact Salt lake center now on one three one point two five (131.25). "Roger, Nine Bravo Victor,	eight thousand. . .2 miles (14.8 DME before **Crossing SHONE,** and turning direct to Twin Falls pilot receives another ATC hand-off. (or at time pilot reports X-tion.		**vs. Comm.** **9. Aviate vs. Navigate vs. Communicate**
Contact Center: Time of MS:	"Salt lake center, Cessna seven eight nine Bravo Victor is with you at eight thousand. "Nine Bravo Victor, Ident. "Roger, Recycling transponder, Ident,	"Cessna Nine Bravo Victor, Salt lake center, Ident. Altimeter two niner niner two Cessna nine Bravo Victor, radar contact lost. Recycle transponder, Ident "Cessna nine Bravo Victor, reset transponder,	Radar contact lost.	Radar contact lost, and **pilot must recycle, and reset transponder.**	**10. Aviate vs. MS**

Comm. Time: MS time: Resolution: Yes/No	"one seven one four, nine Bravo Victor, "One one eight point five, nine Bravo Victor.	squawk one seven one four (1714), "Cessna nine Bravo Victor Radar contact, "Cessna nine Bravo Victor, contact Twin falls approach now, one one eight point five (118.5) ,they can give you current ATIA, Have a good day.	Approaching 2nd fix on route, 20 miles from Twin Falls VOR Pilot receives hands-off then,		**11. Aviate vs. Comm.**
Contact Twin Falls approach:	"Twin Falls approach, Cessna seven eight nine Bravo Victor is with you at eight thousand, "two niner niner two, nine Bravo Victor,	"Cessna Nine Bravo Victor, radar contact. Twin falls altimeter is two niner niner two.			

Twin Falls ATIS: Comm: Response:	"Roger Ready to copy ATIS, *("Thank you,)*	Cessna nine Bravo Victor, if you are ready, we can give you ATIS information for Twin Falls. ATIS: Twin falls Airport information Uniform. One six zero zero Greenwich weather, Measured ceiling six hundred overcast, visibility half mile in fog. Wind two six zero at four. Temperature two six, altimeter two niner niner two. ILS runway two five. Advise you have Uniform.		Pilot asked if ready to copy ATIS; ATC reads ATIS to pilot outloud.	**12. Aviate vs. Comm**
Handoff to Twin Falls approach #2: Comm: Response:	"Roger, nine bravo victor leaving eight thousand, descending seven thousand, "Twin Falls approach One two six point seven, nine Bravo Victor, "Twin Falls approach, Cessna seven eight nine Bravo Victor is with you at seven thousand with Uniform.	"Cessna Nine Bravo Victor, descend and maintain seven thousand, "Cessna Nine Bravo Victor, contact Twin Falls Approach now, one two six point seven (126.7).	**@7020** 20 ft. before reaching seven thousand, pilot handed off to Twin Approach;		**13. Aviate vs. Comm**

Comm: Response:	"Roger, leaving seven thousand, descending six thousand five hundered, nine Bravo Victor,	"Cessna Nine Bravo Victor, Twin falls approach. Descent and maintain six thousand five hundred, expect ILS approach runway two five. Wind is two three zero at three, altimeter two niner niner four.			
MS time: Resolution: Yes/No			**@6520** 20 ft. before reaching six thousand five hundred. Manage system task: **Carb Heat "On" (F4)**		**14. Aviate vs. Manage System**
Comm: Response:	"one three six point six, nine Bravo Victor, "Twin falls approach, Cessna nine Bravo Victor with you at six thousand five hundred,	"Cessna nine Bravo Victor, contact Twin falls approach one three six point six (136.6). "Roger Cessna nine Bravo Victor, stand by, "Cessna Nine Bravo Victor, the localizer just went out of	Pilot handed off to Twin Approach;		

Comm: Response:		service, expect VOR runway two five approach. Report crossing Twin falls VOR.			**15. Aviate vs. Navigate**
	"Roger, VOR Runway two five approach, report crossing Twin Falls VOR, nine Bravo Victor.				**Memory Task**
Comm: Response:	"cleared for the VOR 25 approach Nine Bravo Victor,	"Cessna Nine Bravo Victor, cleared for the VOR runway Two Five approach, with procedure turn,			**16. Aviate vs. Navigate vs. Comm**
	"Twin Falls approach, Nine Bravo Victor is crossing Twin Falls VOR,		.6 miles from twin falls VOR, pilot cleared for approach.		
	"Procedure turn outbound, Nine Bravo Victor,	"Cessna Nine Bravo Victor roger, report procedure turn outbound		Pilot must maintain published altitude for approach: Pilot must remember to report procedure turn inbound.	**Memory Task**
Time MS: Resolution: Yes/No	"Twin Falls approach, Nine Bravo Victor is procedure turn outbound,	"Roger Nine Bravo Victor,	Manage systems task: **Flaps retracted 10 degrees (F8)**	When established on outbound course and leveled ?	**17. Aviate vs. Manage Systems**

	"One one eight point two, Nine Bravo Victor	"Cessna Nine Bravo Victor, contact Twin Falls Tower on one one eight point two (118.2).	When starting to get established on the Localizer, at 1-2 dots of VOR center needle deflection turning to the radial. Pilot handed off to Tower		**18. Aviate vs. Navigate vs. Comm.**
Contact Tower:	"Twin falls tower, Cessna seven eight nine Bravo Victor is with you, "Nine Bravo Victor, report Strik outer marker,(or 3 miles)	"Cessna Nine Bravo Victor, Twin falls tower, report the Strik outer marker, *(or three miles outside Twin Falls VOR)*		When established on the localizer, pilot calls Tower. Pilot must remember to report Strik outer marker	**Memory Task**
MS Time: Resolution: Yes/No	"Nine Bravo Victor, Strik inbound,	"Cessna Nine Bravo Victor, cleared to	MS task: **Landing Gear UP. (F9)**		**19. Aviate vs. MS**

Landing Time:	"Roger, Cleared to land runway Two Five.	Victor, cleared to land runway Two five. Wind calm. "Cessna nine Bravo Victor, turn left or right next intersection, contact ground, one two one point seven (121.7) when clear. **:End of Scenario:**	Breaking out at 500ft. above the airport, runway in site. Change flight recorder file name…..		
Contact Ground	"Twin Falls ground, Cessna seven eight nine Bravo Victor clear of the active, taxi to parking.	"Cessna Nine Bravo Victor, ground, taxi to Parking…….			

APPENDIX 9: Victor Scenario Script

Tasks	Pilot	Controller	Events	Comments	Challenge
IFR Flight Plan Twin falls to Burley:	FSS: IFR 234 Sierra Bravo, Cessna-182 slash Alpha, one three zero knots, Twin Falls, 2300 Zulu, one zero thousand feet, Victor-142 Ocley, Burley direct. Destination Burly, one hour, five hours fuel, alternate Jackpot, Name: John Doe, on file at Airviation, one on board, aircraft is Gold on White".	"Okay, have a good day		Verbally call out flight plan to pilot.	
Listen to ATIS: 135.7	Tuned to ATIS frequency 135.7	ATIS: Twin Falls Terminal, Airport information Delta, (two three zero zero) Zulu weather. Indefinite ceiling five hundred, sky obscured, visibility one half, light rain and fog, temperature three four, dew point three two, wind calm,		Ask pilot to dial ATIS when ready to copy, read out ATIS to pilot.	

		altimeter two niner niner two. VOR runway Seven in use, landing Runway Two Five and seven, Departing runway Two Five. Advise Twin Falls Clearance on 123.6 you have information Delta".			
Call Clearance Delivery: 123.6	"Twin Falls Clearance, Skylane Two three four Sierra Bravo, IFR to Burley with Delta.	November Two three four Sierra Bravo is cleared to the Burley municipal airport via after departure Runway two five, maintain runway heading, expect radar vectors to Victor-142 as filed. Climb and maintain six thousand, expect nine thousand one five minutes after departure. Departure frequency			

	"Repeat Clearance	will be one two six point three (126.3). Squawk four three four seven (4347). "Cessna four Sierra Bravo, read back is correct, Have a good flight.			
Contact Ground 121.7	Ground control: "Twin falls Ground, Cessna Two three four Sierra Bravo at Airviation with Delta and clearance. Ready to taxi "Roger, Taxi to Runway Two Five.	"Cessna Four Sierra Bravo, taxi to runway Two Five. Wind is two three zero at five, altimeter two niner niner two.			
Contact Tower: 118.2	"Twin Falls Tower, Cessna Two three four Sierra Bravo is ready on Two Five.	"Cessna Four Sierra Bravo, taxi into position and hold, traffic landing			

Takeoff time:	"Roger, position and hold on two five, "Four Sierra Bravo, cleared for takeoff.	runway three zero. (wait 1 minutes) "Cessna Two three four Sierra Bravo, cleared for takeoff.		Tim should be recorded at takeoff. After takeoff, and before reaching altitude by 50 ft. Pilot is requested to contact Departure.	
Time of MS: Resolution: Yes/No Comm: Response:	"Four Sierra Bravo, one two six point three."	"Cessna four Sierra Bravo Contact departure now on one two six point three (126.3). Have a good flight."	Plane enters clouds at 500ft. AGL (4651 MSL). During climb: Manage systems task: **Carb Heat (F4)** **@5980** 20ft. before reaching 6000 ft. altitude, pilot handed off to departure.		**#1: Aviate vs. Manage systems** **#2. Aviate (altitude) vs. Communic ate (departure)**
Contact departure Time recorded: Comm: Response:	"Departure, Cessna Two three four Sierra Bravo is with you at six thousand.	"Cessna Four Sierra Bravo, Twin Falls Departure, radar contact. Make left turn, Proceed direct to Twin Falls VOR. Join Victor-142 on course to		Pilot must remember to report crossing VOR.	**Memory Task:**

Time of MS: Resolution: Yes/No Time Comm: Response:	"Leaving six thousand, climbing seven thousand, proceed to Twin Falls VOR, then Victor-142 to Ocley, Four Sierra Bravo, report crossing VOR, "One two five point Two, (*and crossing VOR),* Four Sierra Bravo, "Twin Falls Departure, Cessna Two three four Sierra Bravo is with you at seven thousand (*crossing*	Ocley, climb and maintain seven thousand. Report crossing VOR. "Cessna Four Sierra Bravo, contact Twin falls Departure on one two five point seven (125.7).	While tracking the VOR Manage systems Task: **Cowl Flaps" (F5 or 5(** **.6 miles** DME from Twin Falls VOR pilot asked to switch frequency to Twin Falls departure on one two five point seven five. Crossing the VOR, pilot must establish	Manage systems light will light, indicating a manage systems task	**3. Aviate vs. Manage Systems:** **4. Aviate vs. Navigate vs. Comm** **5. Aviate vs. Navigate**

Comm: Response:	*TWFS. VOR)* "Leaving seven thousand, climbing eight thousand, Four Sierra Bravo "One two six point zero, Four Sierra Bravo.	"Cessna four Sierra Bravo Roger, radar contact, climb and maintain eight thousand. "Cessna Two three four Sierra Bravo, contact Salt lake Center now, one two six point zero (126.0).	on the Victor airway. **@ 7980** Twin Falls Departure hands off to contact Center 20 ft. before eight thousand.		**6. Aviate vs. Comm.**

Contact Salt Lake Center	"Salt lake center, Cessna Two three four Sierra Bravo is with you at eight thousand. "Four Sierra Bravo, Ident.	"Cessna Four Sierra Bravo Salt lake center, Ident. Altimeter two niner niner four. "Cessna Four Sierra Bravo, radar contact. Climb and Maintain nine		Pilot must remember to report crossing Ocley intersection.	**Memory Task**

Time of MS: Resolution: Yes/No Comm: Response:	"Four Sierra Bravo, leaving eight thousand, climbing to nine thousand, report crossing Ocley intersection, "Four Sierra Bravo, is 15 miles from VOR, and tops at 7500, "Leaving nine thousand, climbing to ten thousand Four Sierra Bravo	thousand. Report crossing Ocley intersection. "Cessan four Sierra Bravo, can you report distance from Twin falls VOR, and tops? "Cessna four Sierra Bravo, Thank you. "Cessna four Sierra Bravo, climb and maintain one zero thousand	**@8980** 20ft. before reaching nine thousand. Manage Systems task: **Master Alt. Side "Off" (F1)**		**7. Aviate vs. Comm. Vs. MS**
	"Four Sierra	"Cessna Four Sierra Bravo, Salt lake center, Ident.	@15 miles "fr" VOR (when established and on		

	Bravo, Ident.		altitude if possible)		
MS time:	"Roger, Recycling transponder, Ident,	Cessna four Sierra Bravo, radar contact lost. Recycle transponder, Ident		Transponder lost, pilot must recycle, and reset transponder.	**8. Aviate vs. MS**
	"two seven two four, four Sierra Bravo,	"Cessna four Sierra Bravo, reset transponder, squawk two seven two four (2724),	Manage systems: **Transponder errors**		
	"Leaving ten, descending to nine thousand five hundred, Four Sierra Bravo,	"Cessna four Sierra Bravo Radar contact, "Cessna Four Sierra Bravo, Descend and maintain nine thousand five hundred,			
MS time: Resolution: Yes/No					**9. Aviate vs. MS**
Comm: Response:			**@ 9520** ft. Manage Systems Task: **Pitot heat "Off" or "On" (F3).**		
Comm: Response:	"Cessna Four Sierra Bravo is crossing OCLEY intersection,		Immediately after **Crossing OCLEY**, AND		**10. Aviate vs. Navigate vs. Communicate**

Contact Center #2	"One three one point two five, Four Sierra Bravo. "Center, Cessna Two three four Sierra Bravo is with you at nine five. "Leaving Nine five, descending to nine thousand, Four Sierra Bravo, "One two eight point five, four Sierra Bravo.	"Cessna Four Sierra Bravo, contact center now on one three one point two five (131.25, "Cessna Four Sierra Bravo, Salt lake center radar contact, "Four Sierra Bravo, Descent and maintain nine thousand "Cessna four Sierra Bravo, contact Haily approach, one two eight point five (128.5), they'll give you current Burley ATIS, Have a good day.	TURNING DIRECT TO Burly, pilot receives another ATC hand off **@9020** 20 ft. before 9000, and Approaching 2nd fix on route, 20 miles from Burley VOR Pilot receives hands-off		**11. Aviate vs. Comm.**

Contact Haily approach:	"Haily approach, Cessna Two three four Sierra Bravo is with you at nine thousand,	"Cessna Four Sierra Bravo, radar contact. Burley altimeter is two niner niner zero.			
Comm:	"two niner niner zero, four Sierra Bravo,			Pilto askedfor ATIS, ATC will report ATIS to pilot.	
Response:	"Ready to copy, Four Sierra Bravo,	"Cessna Four Sierra Bravo, when ready, we can give you Burley ATIS information		Pilot must control aircraft while receiving ATIS for Burley airport.	**12. Aviate vs. Comm**

Burley ATIS:	"Roger, have Charlie, Thank You.	ATIS: Burley Airport information Charlie. One six zero zero Greenwich weather, Measured ceiling six hundred overcast, visibility one mile. Wind zero six zero at four. Temperature two six , altimeter two niner niner two. VOR DME Bravo. Advise you have Charlie.			
	"Descending to eight thousand, four Sierra Bravo	"Cessna two three four Sierra Bravo, descend and maintain eight thousand,	After ATIS.		
Handoff to Burley approach: Comm: Response:	"Burley approach One two seven point seven, four	"Cessna Four Sierra Bravo, contact Burley Approach now, one two seven point seven (127.7).	**@ 8020** 20 ft. before reaching 8000, pilot handed off to Burley Approach.		**13. Aviate vs. Comm.**

	Sierra Bravo, "Burley approach, Cessna Two three four Sierra Bravo is with you at eight thousand with Charlie. "Roger, leaving eight thousand, descending to seven thousand, and expect the VOR Alpha approach, Four Sierra Bravo, "one two zero point three, four Sierra Bravo, "Burley approach, Cessna four	"Cessna Two Three Four Sierra Bravo, Burley approach. Descent and maintain seven thousand, revised runway approach in use. Expect the VOR Alpha approach with procedure turn. Wind is zero three zero at three, altimeter two niner niner two. "Cessna four Sierra Bravo, contact Burley approach one two zero point three (120.3)	**@7020** 20 ft. before reaching seven thousand, pilot handed off to Burley Approach;	Pilot must review new approach plate and maintain aircraft control.	**14. Aviate vs. Navigate (vs. Comm)** **15. Aviate vs. Comm**
Contact Burley Approach:					

	Sierra Bravo with you at seven thousand,				
		"Roger Cessna four Sierra Bravo, stand by,		Pilot must remember to report crossing VOR.	**Memory Task**
Comm: Response:	"Roger, cleared for the VOR Alpha approach circling Runway six. Report crossing Burley VOR, four Sierra Bravo.	"Cessna Four Sierra Bravo, cleared for the VOR Alpha approach runway six. Report crossing Burley VOR outbound.			**16 Aviate vs. Comm vs. Navigate**
MS time: Resolution: Yes/No			Pilot must maintain approach altitude as charted for approach.		**Memory Task**
	"Burley approach, Four Sierra Bravo is crossing Burley VOR,			Pilot must remember to report procedure turn inbound	
		"Cessna Four Sierra Bravo roger, report procedure turn inbound			**17. Aviate vs. MS**
Comm: Response:	"Procedure turn inbound, Four Sierra Bravo,		Manage systems: **Landing gear UP or Down (F9)**	Tracking the radial outbound, established and on altitude?	

	"Burley approach, Four Sierra Bravo is procedure turn inbound, "One one eight point nine,	"Roger Four Sierra Bravo "Cessna Four Sierra Bravo, contact Burley Tower on one one eight point nine (118.9),	Establishing on the VOR radial for approach, (1 to 2 dots off center of VOR needle) pilot handed off to Tower:		**18. Aviate Vs. Navigate vs. Comm.**
Contact Tower:	"Burley tower, Cessna Two three four Sierra Bravo is with you "Four Sierra Bravo, report	"Cessna Four Sierra Bravo, Burley tower, report crossing the Burley VOR	**@5520, or 2-**	When established on the localizer, pilot calls Tower. Pilot must remember to report crossing VOR.	**Memory Task**

Landing Time:	over Burley VOR, "Four Sierra Bravo is 3 miles from Burley VOR. "Four Sierra Bravo, is over Burley VOR, "Roger, Cleared to land runway six,	"Cessna Four Sierra Bravo, can you report distance from Burley VOR. "Roger, Thank You, "Cessna Four Sierra Bravo, cleared to land circling runway six. Wind Calm. "Cessna four Sierra Bravo, turn left or right next intersection, contact ground, one two one point nine when clear. **:End of Session:**	**3 miles outside VOR,** descending to Minimum altitude, pilot asked to report position. Breaking out of 500ft. above the airport, runway in site. **<u>Change Flight recorder file name</u>**		**19. Aviate vs. Navigate**
Contact Ground	"Burley ground, Cessna Two three four Sierra Bravo clear of the active, taxi to parking.	"Cessna Four Sierra Bravo, ground, taxi to Parking…….			