

2-2000

## A Comparative Study of Novice vs. Experienced Pilots Utilizing Cockpit Models Applied to the Multi Function Display System

Susan J. Karkman

*Embry-Riddle Aeronautical University - Daytona Beach*

Follow this and additional works at: <https://commons.erau.edu/db-theses>



Part of the [Aviation Commons](#), and the [Psychology Commons](#)

---

### Scholarly Commons Citation

Karkman, Susan J., "A Comparative Study of Novice vs. Experienced Pilots Utilizing Cockpit Models Applied to the Multi Function Display System" (2000). *Theses - Daytona Beach*. 92.

<https://commons.erau.edu/db-theses/92>

This thesis is brought to you for free and open access by Embry-Riddle Aeronautical University – Daytona Beach at ERAU Scholarly Commons. It has been accepted for inclusion in the Theses - Daytona Beach collection by an authorized administrator of ERAU Scholarly Commons. For more information, please contact [commons@erau.edu](mailto:commons@erau.edu).

**A Comparative Study of Novice vs. Experienced Pilots  
Utilizing Cockpit Models Applied to the Multi Function  
Display System**

by  
Susan J. Karkman

Embry-Riddle Aeronautical University  
Daytona Beach, FL 32114  
February, 2000

UMI Number: EP31932

### INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI<sup>®</sup>

---

UMI Microform EP31932  
Copyright 2011 by ProQuest LLC  
All rights reserved. This microform edition is protected against  
unauthorized copying under Title 17, United States Code.

---

ProQuest LLC  
789 East Eisenhower Parkway  
P.O. Box 1346  
Ann Arbor, MI 48106-1346



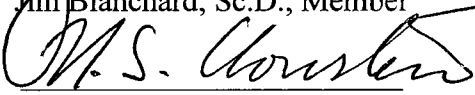

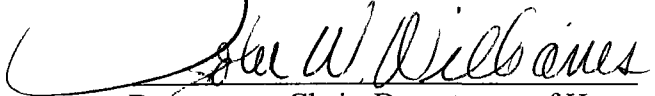
# A Comparative Study of Novice vs. Experienced Pilots Utilizing Cockpit Models Applied to the Multi Function Display System

by

Susan J. Karkman

This thesis was prepared under the direction of the candidate's thesis chair, Dr. John Wise, Department of Human Factors and Systems, and has been approved by the members of this thesis committee. It was submitted to the Department of Human Factors and Systems and was accepted in partial fulfillment of the requirements for the degree of Master of Science of Human Factors & Systems Engineering

THESIS COMMITTEE:

  
John A. Wise, Ph.D., Chair  
Jim Blanchard, Sc.D., Member  
Hal Christensen, M.A., Member  
HFS Graduate Program Coordinator  
Department Chair, Department of Human Factors and Systems

## ACKNOWLEDGEMENTS

I wish to express special thanks to my thesis chairman, Dr. John Wise for his guidance, suggestions and encouragement that were crucial for the completion of this thesis project. I would also like to thank Jim Blanchard for his patience and guidance with the practical suggestions. A special thanks also goes out to professor Hal Christensen who gave me tremendous editorial and moral support throughout the development of the study.

## ABSTRACT

**Author:** Susan Karkman  
**Title:** A Comparative Study of Novice vs. Experienced Pilots Utilizing Cockpit Models Applied to the Multi Function Display System  
**Institution:** Embry-Riddle Aeronautical University  
**Degree:** Master of Science in Human Factors and Systems  
**Year:** 2000

Based on previous research findings in the expert/novice area, this thesis suggests that how people approach and solve problems largely depend on their experience level. The literature supports that experts tend to prioritize their actions differently than their novice counterparts as they negotiate their way through various critical flight scenarios. In this study we assume this difference is, in part, related to the fact that experts have a more complete understanding/perception of the overall situation than do novices. Psychologists often refer to this understanding as a more complete mental model.

The purpose of this study was to evaluate if the proposed format of the ICIS will effect performance of novice pilot's as compared experienced pilots. In order to establish the potential difference in expert/novice problem-solving, a perception task was assigned to the participants. Specifically, the task was to rank pertinent flight information according to how the pilot perceives the items related to

the scenario which she is presented via the display program. As is suggested throughout the literature aligned to this study, the results indicate that as a person gains experience ranking relevance differ. The perception test developed for this study was used to establish this assumed difference. Further indicated in the literature by Ericsson and Charness (1994), differences in expertise provide the largest and most reliable differences in performance between individuals. Therefore, in order to test the claimed effectiveness of the new touch-screen display, the research focused on performance measures.

In this study both groups were asked to solve similar flight scenarios solely with the help of the ICIS display. The performance of the participants was based on their ability to find flight information on the screen, the amount of keystrokes they used, and the time they needed to solve the problem. It was assumed the ICIS's highly structured organization and would effectively guide the user through the problem-solving process, with a significant improvement in human-computer interaction graphical touch-screen display performance.

Cognitive load theory suggests that available information should support structures which eliminate any excess load on working memory in order to enhance learning. The literature further explains that as individuals store learned information in long-term memory, this process reduces the burden on working memory by allowing multiple elements of information to be treated as a single or unified response (Kalyuga, Chandler & Sweller, 1998).

Similar, in cognitive terms, to "chunking," this layering is thought to provide benefit to the novices and experts alike in navigating computer interfaces. As a basis for

design effectiveness, this study tested hypotheses using the ICIS. Seeking to support the notion that several layers of information on one display provides equal reduction of working memory, regardless of the participants' level of flight experience. This study supports the assumption that layering provides benefit to the user of the ICIS, regardless of experience level.



## TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	iii
ABSTRACT.....	iv
CHAPTER ONE: INTRODUCTION.....	1
Cockpit Technologies for General Aviation Application.....	1
The Integrated Cockpit Information System.....	2
Purpose of the Study.....	4
CHAPTER TWO: LITERATURE REVIEW.....	7
Experience Level Effects.....	7
Knowledge Structures.....	9
Practice.....	9
Problem Solving Techniques.....	11
Cognitive Schema.....	13
Mental Models.....	15
Cognitive Task.....	20
Training.....	21
Routines.....	21
Knowledge Elicitation Techniques / Findings.....	22
Measurement of Mental Models.....	23
Situational Awareness.....	28
Relevant Design Issues for the Present Experiment.....	41

The Integrated Cockpit Information System.....	44
Summary of the Literature and Research Hypotheses.....	45
CHAPTER THREE: METHODOLOGY.....	49
Participants.....	49
Instruments.....	50
Perception Instruments.....	51
Procedure.....	51
CHAPTER FOUR: DATA ANALYSIS AND RESULTS.....	54
Statistical Analysis.....	54
CHAPTER FIVE: DISCUSSION.....	57
CHAPTER SIX: RECOMMENDATIONS AND LIMITATIONS.....	61
REFERENCES.....	63
APPENDIX A.....	66
ICIS Description.....	67
ICIS Hardware.....	69
APPENDIX B.....	70
Informed Consent Form.....	71
Pilot Perception Test.....	72
APPENDIX C.....	75
Post Hoc.....	76

## **CHAPTER ONE: INTRODUCTION**

### **Cockpit Technologies for General Aviation Application**

As a part of nation wide attempt to improve general aviation in the age of rapidly advancing technology, the National Aeronautics and Space Administration (NASA) and the related agencies have combined efforts to develop advanced technologies applied to pilot training systems. NASA is currently involved in several aviation research programs specifically applied to general aviation. One of the major programs in this commitment to improved training technologies is the Advanced General Aviation Transport Experiments (AGATE). This collaborative program reflects a combined effort of the Federal government seventy related aviation industries which are systematically coupled with selected university consortiums. The program is an integrated effort to revitalize the declining general aviation community.

Today, most general aviation airplanes use forty-year old technology which by today's standards results in limited effectiveness. Conversely, the number of aviators is constantly declining. In an attempt to reverse this trend, the program is committed to finance the costly process of developing and coordinating new standards for advanced technologies. The AGATE consortium is committed to funding half of the total program development cost. NASA is matching the other fifty percent of what the industry members invest in the project (AGATE, 1998). The consortium of investors assigned with aviation curriculum are encouraged to design improved aviation training technology as a component of the program involvement. The purpose and objective is to develop and standardize future cockpit technologies.

## **The Integrated Cockpit Information System**

One of the principle designs of this research activity is the integrated . This new and innovative technology might serve as a replacement of the traditional round dial equipment currently in use. The integrated cockpit information system (ICIS), as it is also referred to, is designed to simplify/organize tasks with the help of a glass cockpit layout. The ICIS allows for a less cluttered cockpit work environment by presenting pertinent information in an organized fashion on a single display.

It is suggested by the literature that information should be structured to eliminate overloading working memory with the help of schemas. A schema is defined as a cognitive construct that permits people to treat multiple supplements as one. In other words, people tend to group information into related categories which it will be employed by pilots in the flight environment. The literature further suggests that schemas help store information in long-term memory thus reducing the burden on working memory as they establish images and an understanding of how things fit together.

Information can be processed either consciously or automatically, with varying levels of automaticity. A schema can be stored/retrieved from long-term memory either in a automated format or as individual elements requiring conscious consideration. It is suggested in the literature that if a schema can be brought into working memory in automated form, it will free up working memory for other events such as problem solving.

Working memory limitations is today a major consideration in typical instructional design. The cognitive load theory on the other hand, is based on the assumption that working memory is limited and that skilled and improved performance is

a result of experience whereby automated schemas have been stored in long-term memory. The cognitive load theory further assumes that information presented to new learners should be structured in such a manner as to eliminate any avoidable load on working memory and maximize the acquisition of automated schemas (Kalyuga, Chandler & Sweller, 1998). Based on this information, it is suggested that the ICIS's structured layout may reduce unnecessary high cognitive load, which concurrently may result in freeing up working memory. It is further suggested that novice users will benefit from physically integrating multiple sources of information which, in turn, tends to reduce the need for mental integration (Kalyuga, Chandler & Sweller, 1998).

Another appropriate issue related to this study is to discuss the use of metaphors and subsequently the development of a mental model. Metaphors are a component of the mental model development process as they act as simplified representations of concept of a not yet formalized mental model. These concepts appear not to be stable over time and future change as the model becomes more defined and detailed. In other words, the metaphor is the beginning of a fully developed mental model where information is perceived through the individual metaphor or the overall mental model (Hill & Levenhagen, 1995). As pilots gain experience, the metaphorical language may be retained but the metaphors are replaced by an overall picture, a mental model. In short, experience affects performance. In this study the assumption is that the new display will reduce the load on the working memory, and aid the development of a mental model.

It is suggested that the ICIS display learning model provides the user with metaphors that can be used for the initial development of a mental model. The software utilizes touch screen capabilities that enables the user to access flight information easily.

The ICIS is used as a tool to measure the use of a mental model in the problem solving process. The design of the ICIS attempts to provide the user with a structured mental picture that integrates vital flight information from multiple sources into one single graphical display. The information is displayed in the form of filters where related information is grouped into categories. The categories can be accessed through the filters and multiple information layers are displayed. The pilot can see traffic, weather systems, terrain, airport locations, as well as re-plan the entire flight route directly on the screen. Within each filter the pilot can access more specific information about, for example, the weather. In the weather filter, information about winds, temperature and radar are displayed. This structured approach of displaying flight information is assumed to help the pilot reach sub-goals that ultimately will allow the user to arrive at her goal of successfully negotiating a flight situation. The main screen tracks the aircraft's path throughout the flight, on a color display, much like a GPS moving map equipment. Moreover, the ICIS also introduces a new alerting system that automatically advises the pilot of approaching hazards, such as weather, traffic and other imminent dangers. The system claims to be effective with appeal to the general aviation public.

### **Purpose of the Study**

The purpose of this study is to focus on the use of a mental model by comparing a group of high time experienced pilots to a group of low time novice pilots with reference to their reported performance using the ICIS as a measurement tool. In general, the literature review supporting this study indicates that experts tend to solve problems in the cockpit more efficiently than their novice counterparts. The problem-solving process is described as a gap between a present situation and a desired goal, as for example when an

individual is introduced to a situation not previously encountered or where a solution from past experiences is not known or applicable to the new situation (Huitt, 1992). With this in mind, it is reasonable to link experience level to more efficient processing. If a problem/situation has been experienced in the past, the solution will come quicker and response time will be shortened. Thus, providing a safety net in the actual flight environment.

Mental models tend to expedite this mental linkage. Mental models are said to provide predictive and explanatory power for understanding an interaction as they are coupled with prior knowledge and understanding. Wilson and Rutherford (1989) suggest that a mental model is a representation formed by a user of a system based on previous experience as well as current observation that dictates the level of subsequent task performance. Even though the mental model notion is still under continual theoretical development, consensus exists that models are used to guide human behavior (Mogford, 1991). Also, researchers suggest that an attractive presentation help people put things in perspective. The mental model acts as a direction seeker/giver as people try to understand new environments (Wilson & Rutherford, 1989). The expert uses mental models that come from experience and, according to previous research in this area, tend to be more complete than those held by the novice. As is supported throughout the following literature review, experience and training provide the individual with a more complete, improved levels of mental pictures as they usually have been exposed to a greater variety of different situations.

This experience can be used to organize the complexity of a task based on solutions which has been successful in the past. As these models evolve and are

internalized, an experienced pilot may have the ability to accurately project future states as she makes decisions in a particular situation (Endsley & Bolstad, 1994). This study uses the ICIS to determine if it helps the pilot to develop an appropriate mental picture that will expedite the learning process.

If there is a significant difference in performance between the two groups, the ICIS's projected effectiveness may or may not be established. Thus, it is assumed that the appropriate mental model and use of metaphors may not have been provided. However, if no significant difference is found, the ICIS may provide a good guidance that assists the pilot in the critical problem-solving process. Furthermore, it might have a potential future in the general aviation community as it suggests usability to aviators of varying level of experience. This could ultimately make flying safer, more attractive and satisfying through easier mastery of skills needed by the general aviation public.

The literature further suggest that difficult scenarios are correlated with a significant difference in performance. In other words, if a task is difficult to perform, a greater difference in performance will be evident between experts and novices. In this study that would be indicated by a greater difference in time, keystrokes and ranking scores on the perception test. Therefore, it is resonable to assume that the most complicated scenario will indicate a significant difference in scores as it is correlated with how difficult a task is perceived to be. To analyze this assumption, a post hoc test was included in this study to evaluate difficulty level.



## CHAPTER TWO: LITERATURE REVIEW

### Experience Level Effects

According to Kahney (1986), people differ in how they approach a problem, based on experience level with a certain problem, because they pay attention to different things. As we shall see, several theories support the concept that people typically advance through distinct learning stages and consequently approach problems differently as a result of experience. Dreyfus and Dreyfus (1986) concur with this notion of experience and practice. They make an interesting analogy between what they refer to as “knowing that” and “knowing how.” People are able to drive a car or ride a bicycle without putting much effort into the underlying thought process. It is believed that this is possible due to prior experience and practice. As such, we do not have to depend on rules/procedures and think about each step to perform (knowing that) once an activity has been thoroughly learned. Some things that we perform without effort daily (knowing how) are even too complex to be reproduced or explained in a step-by-step manner. According to the text, when we start thinking about the process we go through to perform a task, chances are that our performance will be significantly degraded. Humans tend to acquire new skills through experience/instruction and do not just jump from the “knowing that” to “knowing how” stage. A five-step process has been proposed to advance from being a novice to expert level. The authors caution that one should be aware of the fact that not all people will reach the expert level, but individuals in a certain stage will outperform individuals of the earlier stages of this model. Stage one is the so-called novice stage. In this stage the student learns to recognize objective facts in a context-free environment. In other words, rules are applied without considering the big

picture of the situation. Stage two is the advanced beginner phase. Here, the learner copes with concept-free facts and considers the overall situation. For example, instead of merely shifting gears at a certain speed (novice stage) the learner now takes into account other factors such as engine sound and traffic. The third stage is the competence stage where more experience reflects a hierarchical procedure for decision-making.

Experience allows the individual to simplify the situation and evaluate his options.

According to the authors, the novice and the advanced beginner simply apply learned rules but do not feel responsible for the outcome. However, once the learner has reached the third stage, this “detached” feeling is left behind and becomes more involved in the situation. The fourth stage is the proficiency stage. This stage allows us to respond intuitively to patterns without thinking about the individual steps involved. This effortless understanding occurs, as we are able to discriminate important features based on previous experience. The authors use “intuition” and “know-how” interchangeable in this context. Even though the learner is able to evaluate the situation, the person still thinks analytically about what to do. The last and also the highest level suggested in this knowledge acquisition model is the expert stage. On reaching this stage, the learner bases decisions on experience and does not have to consciously think about the thought process involved. In a sense, the expert becomes one with the task as no rules or procedures are applied and he just does what usually works. With enough experience and practice the proficient performer seems to group situations with goals to arrive at decisions best suited for the situation at hand. In the expert stage the situation is evaluated and a fitting solution simultaneously comes to mind based on prior experience.

This progression through the five stages, the changed perception of the task and the associated behavior demonstrate the skill acquisition process. According to the authors, this process allows us to advance from analytical (novice), concrete reasoning to a more abstract thinking pattern. As we have seen, the beginner recognizes individual elements in a detached manner, whereas more experienced individuals who have advanced to the higher levels in this model base their decision making on holistic pairings of new situations with associated solutions based on past experiences.

### Knowledge Structures

This five stage model is based on unstructured problem situations. These areas usually involve situations with an unlimited number of relevant elements and ways of approaching the task. The more structured problems include tasks where concrete solutions exist, such as when dealing with math formulas. The more unstructured the task, the more experience and a higher skill level is required to effectively deal with the situation (Dreyfus & Dreyfus, 1986).

### Practice

Another result of practice is reduced response time. Several research findings in this area suggest that both accuracy and latency in several paired-association learning tasks have shown a drop in response time as a result of practice. Once proceduralized performance becomes dominant, as opposed to performance driven by declarative knowledge, there is a distinct drop in response time. In order to improve the educational aspect, a more proceduralized teaching approach should be implemented. The text

suggests that expert performance involves a sequential execution ability of complex procedures that mainly is the result of extensive experience. With practice these smaller procedural pieces becomes more or less automated and can be combined into longer, more efficient, sequences (reduced response time/increased accuracy).

Morris (1987) agrees with Alan on this issue of distinct differences between expert and novice performance. According to Morris, novices are less efficient when it comes to executing procedures and also need to rehearse steps declaratively. A novice starts off by using general procedures to retrieve segments of the declarative representation of instructions and then translate them into actions. With experience the learner constructs a specific set of actions that directly incorporates the relevant declarative knowledge, without having to go through the extra effort of retrieving this information from declarative memory. As the set of actions is compiled and efficient, skill performance improves drastically as time required to solve a problem is reduced. Performing the task becomes easier and requires less attention. With this information at hand, we can conclude that declarative knowledge is not as important to experts as it seems to be in the initial stages of skill learning. To find an optimal procedure is both time-consuming and tedious. However, skilled performance involves not only the ability to retrieve the best procedure easily and rapidly, but also to know when to apply it.

Now let us turn our attention to some interesting research findings on this topic. Redding, Cannon, and Lierman (1997) conducted an experiment that revealed some important differences between expert and novice problem solving strategies. According to the authors, experts are able to solve situations with fewer actions than their novice counterparts. Experts also tend to have fewer cases in which they need to use alternative

plans or alter their initial actions, suggesting better planning/organizing as well as better understanding of the overall problem. In addition, the study indicates that expert air traffic control specialists tend to use more short cuts to reduce the overall workload.

### Problem Solving Techniques

Another important finding applicable to this study suggests that experts tend to pay more attention to higher priorities, such as planning and simplifying their work by only focusing on the most pressing tasks (Redding, Cannon & Lierman, 1997). The novices, on the other hand, were unable to prioritize actions, as they concentrated on relatively basic tasks, such as marking flight strips and communication. As indicated in the above findings, experts have a tendency to be more economical when it comes to problem solving steps, and they have a more comprehensive picture of the overall scenario. Novices often fail to identify problems and to carry out the planning strategies as efficiently as the experts. The authors suggest that experts have better monitoring skills, as they are able to recognize and predict evolving conflicts faster. This allows the experienced controllers to shift their attention to the overall picture of the situation and prevent so-called tunnel vision. Tunnel vision is common among novices as their attention field narrows to one particular event and the overall picture is ignored when workload is increased. This phenomena is also true of experts but the only difference is the amount of workload that triggers it. The recommendations from this study include emphasizing situation monitoring and planning activities early on in the training environment since this was one of the major factors that differentiated/separated the experts from the novices. Also, problem-solving practices were recommended to expose

the student to various unusual situations. A decision supports system is also suggested as an instructional aid in the future ATC training program. This system would be organized according to a typical so-called mental model of an expert controller. This model would avoid the traditional behavioral ATC task procedures and allow the student to visualize the expert mental model categorization. More research is under way in the area of learning the cognitive style of the expert controller and how it can be applied to the new ATC training program.

Kahney's (1986) work also revealed some interesting performance differences between expert/novices problem-solving techniques. To demonstrate these differences, the author conducted a study in which a group of Ph.D. and a group of undergraduate students were asked to group physics problems according to their similarity in the problem solving process. The more experienced group (Ph.D. students) showed a tendency to group the problems according to fundamental laws of physics. The undergraduate group, on the other hand, based its sorting on diagram similarities on the surface. As is demonstrated in this study, novices approach a problem by attending to what is mentioned in the problem statement rather than getting a broader view of the underlying principles involved. Experts tend to use material presented in the problem and works forward to find an optimal solution. Novices have a tendency to work the problem based on available answers as they try different options to make it fit the ultimate goal.

### Cognitive Schema

Further, Frederico's 1995 research explored the differences between expert and novice recognition of similar situations. According to his findings, experts are assumed

to adhere to schema-driven approaches when making decisions. This schema-driven approach is thought to be recognition primed as opposed to the traditional analytical method of dividing the situation into parts in order to deal with a particular situation. Experts tend to classify a situation and use entire patterns of situations that were successful in the past. Expert decision makers rely on memory to come up with a schema that will fit the classification that is important for proficient performance. Frederico also discusses some general findings about expert skills. Previous research has indicated that experts employ an outstanding organization of knowledge, and that experts are faster and are able to perform with less errors than do novices in their domain. Expert problem solving is believed to be schema-driven whereas novice problem-solving depend on general search strategies. Furthermore, experts tend to be more context dependent than their novice counterparts. Other results from problem solving research have also indicated a difference between experts and novices in their respective knowledge structure, pattern recognition as well as in their performance and accuracy. As a result of experts having a more structured and organized base of knowledge, they are also able to access and use this information more quickly. Frederico furthermore suggests that experts tend to be far more context dependent when classifying situations. During the experiment, the participants were asked to assign relative weight or degree of importance to each of the tactical scenarios. The participants were also asked to explain why they assigned a certain importance to each scenario/associated action. The findings from this experiment might have some impact on future training methods, as we could train people to recognize similar situations and employ schema-driven decision making.

Novices usually have very limited understanding of the problems and the options available to them and due to the inherent limitations of working memory are unable to hold and move all information necessary for forward planning. Kanhey (1986) suggests that one might be able to increase the probability of a problem solver finding the optimal solution by reducing the problem space. The result of reducing the problem space could lead the user to see what path leads to the desired goal. Discovering where the path leads makes it more likely that the problem solver will be able to identify useful sub-goals. Being guided in the act of achieving sub goals, tend to enhance the odds the problem solvers have at arriving at the optimal solution when working on reaching their overall goal. As such, people need experience with a lot of different examples to be able to relate the common elements automatically and use their knowledge to solve sub-problems. Unfortunately, the processes involved in mapping analogs into a generalizable schema is poorly researched and understood. However, researchers suggest that an intuitive attractive presentation help people put things in perspective (Mogford, 1991).

Consistent with this idea, Johnson-Laird (1993) applies his theory of knowledge composition. He claims that the shift from novice to expert appears to depend on knowledge by compilation. Once knowledge is stored, concepts based on our understanding can be used to construct perceptual models. The completeness of the model depends on experience, and as we learn more we effectively add information to the existing internal model. This brings us from the topic of knowledge organization to the next topic of mental models.



## **Mental Models**

The notion of mental models has prompted heated discussions and several different interpretations of meaning and application have evolved over the years. The psychology community considers mental models as a good explanation of mind and behavior. The human factors advocates, on the other hand, tend to extend this theory in order to use the mental model notion as a tool in system or product design. The mental model issue has often been said to be both ambiguous and to have much face validity. In this study, mental models are considered as a tool to increase the total effort of designing a user friendly system. Based on the studies conducted to date, it is evident that a coherent and agreed framework of the mental models issue is needed. Let us take a look at some of the research findings in this area.

Cohen and Thompson (1999) define a mental model as a succinct summary of events or ideas that an individual has in a certain situation. In their view, this model can be either verbal or graphical. It is believed to serve as a tool for decision makers in the decision making process. Mogford (1991) claims that a mental model is the reflection of the understanding a user has of a system and what it is supposed to do. Others claim that the concept of a mental model is that it serves as a direction seeker/giver as people try to understand new environments (Rogers, Rutherford & Bibby, 1992). In effect, the experts use mental models that are built on prior knowledge and, according to previous research in this area, as a person gains more experience the model becomes more complete.

Rogers, Rutherford and Bibby (1992), highlight some criticism of today's mental model literature. Several definitions are presented in the text that outlines a general picture of what the mental model really is. According to the authors, a mental model is

an elaborate structure and can not be represented as a simple isolated structure. A mental model is also a reflection of the user's understanding of a system, how it works, and why it works that way. Kieras (1999) uses the term "engineered system" for a complex system other than computers. The author presents three kinds of knowledge in his paper. The levels are: the how-it-works knowledge, knowledge on how to operate the device (procedures), and knowledge about the behavior of the device. The author suggests that if a situation involves operating some complex system, the only sensible way of defining a mental model is how well the operator understands the equipment at hand. In other words, the author offers these three levels of knowledge as possible answers to what mental models actually consist of. He further suggests that knowledge about how the device works is the best measurement available at the present time. This procedure allows us to measure, not only how well the operator uses the system, but also how well it is understood. We know from experience that most systems operate in a fairly regular and predictive manner. Therefore, most systems can be operated without much training and deep how-it-works knowledge. In the article it is also suggested that these stereotypical/consistent operating procedures across systems allow novices to base their mental model on previous knowledge or other systems. However, the author also points out that a skilled operator tends to be able to isolate problem situations as a result of having more experience with a wider range of situations.

Morris's (1987) studies can easily be linked to prior research. The author reminds us that it is important to distinguish between learning a procedure and acquiring a mental model of a system. Learning a procedure is not the same as having a mental model of a systems operation. In other words, a mental model is not always necessary for proficient

skill performance. For example, an experienced truck driver might have very limited knowledge of how the truck actually works (internal components), but at the same time is highly proficient in the procedures of driving the vehicle. As such, the value of a mental model to the novice learner depends on the type of skill being acquired.

Haynes (1989) puts the explanation of how people understand problems in very simple terms. He states that a person who is trying to understand a problem creates images of objects and relations in his mind which corresponds to objects and relations in the externally presented problem. These internal presentations are the problem solver's internal representation of the problem. Naturally, different people create different views of the same problem. This leads us into the next section on how mental models are related to the problem-solving process.

### **The Role of Mental Models in the Problem-Solving Process**

Concerning mental models in problem solving, Kahney (1986) writes about how mental representations relate to the problem solving process. The author writes that in order to solve a problem people have to form a mental representation of the information given. The initial state, the goal, and the operator are referred to as the problem space. In this theory the problem space is an individual's internal picture of a given problem that may contain more or less information than is stated in the problem itself. As the problem solver tries to relate the initial state to what she knows about other problems of that type, as she goes through different knowledge states, which are defined as the mental model states and mental model operations that the individual undertakes. The author suggest that this is where individual performance differs during the problem solving process,

since people go through different mental states as they approach a problem. Also, experience allows a person to use different strategies and pay attention to different aspects of the problem.

Oakhill and Garnham (1996) have also studied the mental processes involved in the decision-making process. They state that people make decisions by “de-biasing” procedures which in turn help separate and hold in mind a set of alternatives. According to this model, people make inferences about possible outcomes of their options, and it only makes sense that if one knows nothing about the alternatives, one is unable to assess the situation. The mental model theory (MMT) suggests the possibility of focusing the decision-maker on limited alternatives. To do this, a scenario needs to be used that triggers the representation of other courses of action. This finding is believed to be related to the limited number of alternatives that we are able to think about and hold in working memory at one time. The more models we need to consider, the more difficult it seems to be to draw a valid conclusion. As predicted by the MMT, the authors suggest that it is possible to improve decision-making performance when the options are explicit. Leggrenzi and Vittorio further argue that people are both faster and able to arrive at a better solution when they are presented with spatial representations. Visual aids seem to replace the verbal interpretation step that puts a strain on the limits of the working memory.

In another study, Ehrlich (1996) focuses on developing systems that are intuitively easy to use. In her opinion, the user relies on internal representation of the perceived structure and behavior of a particular system. Ehrlich’s specialty is human computer interaction. An important observation from her study has to do with the

differences between expert and novice reasoning. Novices tend to devise a model that represents the world and simulates processes that happen in real time. The experts, or trained scientists, on the other hand, have the ability to construct an internal model that deals with abstract relations and properties. Another important point has to do with mental model construction as we navigate between levels of information. Evidence has indicated that if all information is not readily available to users at one time, they tend to rely on some internal representation instead. It is suggested that if the user is able to navigate through relevant information in sequence, he only has to retain the last page which is visible. Also, they appear to be significant correlation between spatial visualization skills and solution time. The study indicates that people with good visualization skills are able to form a better internal model of the information presented. This correlation between visualization and performance also implies that there is a visual or spatial component in peoples internal models. Ehrlich draws an analogy here with the misconceptions people have of the physical layout of the city they reside in. More often than not, people have incomplete images of the city they live in. Their internal picture is made up of a number of landmarks and other poorly organized spaces. Thus, practical knowledge alone of the city's layout is not sufficient to allow for an accurate formation of an internal representation of the situation at hand. This supports why this study expects the ICIS's visual and intuitive layout of flight information will reduce the gap between expert and novice performance.

## Cognitive Task

A request from the Federal Aviation Administration to redesign the entire air traffic control training curriculum prompted Redding, Cannon, and Lierman's (1997) research on cognitive task analysis. Their research traced the expert in the decision making process and applied these strategies to the training of ATC students. The study attempted to identify the differences in the mental model of an expert (supervisor) as compared to a novice (student). One of the strategies used to identify the cognitive processes of an expert was task decomposition. This method involves dividing tasks into underlying goals and the thinking patterns associated with them. The importance of having a mental model of the situation at hand was also recognized in this study. An expert's mental model allows the controller to picture the knowledge needed to perform a certain task. According to the findings, instead of using procedural methods traditionally applied in training programs, instruction should be organized according to a mental model. This suggests a major shift from teaching text book facts to a broader cognitive organization that in turn will trigger the responses needed. This is a framework for categorizing events and developing an overall understanding of the situation.

## Training

Canas, Bajo, and Gonzalvo (1994) consider the role of mental models in computer programming. In this context mental models refers to the user's presentation of how a system operates. The focus in this particular approach is directed toward enhancing novices' mental models with the help of trace software. Trace allows students to visually

experience the sequence of programming lines and operation of the system as a mental presentation.

Their view is that trace type training situations will facilitate the acquisition of a mental model on previous research. Mayer, for example, has conducted so-called mental model training that presents novices with graphical views on how a specific system operates. The results of the study indicate that this type of mental models training improves novice performance in problem solving. Another study along the same lines suggested a meta course that visually presents what happens in a computer is like a mental representation of the event. This study showed evidence that the novices improved their programming skills as a result of the training when compared to the control group. These studies were mainly intended to improve the novices' mental model of a system.

### Routines

Cohen and Thompson's (1999) ideas with the relationship between mental models and problem solving. The authors suggest that the mental model that is activated in a certain situation is an indication of what has been successful in the past. This model may be retrieval of relevant information from long-term memory. Although the authors studied how teams take initiative in novel situations, they found some interesting findings regarding expert and novice decision making. According to the authors, experts differ in the way they employ knowledge from their mental models and in the thinking strategy they use. In novel non-routine situations, experienced individuals work to classify their goals and to have a clear understanding of purpose. This understanding tends to help the

more experienced individual to focus her attention on the most critical features of the information and be more effective when selecting her actions. According to Thompson, Jamieson, and Hendy (1997), well-developed mental models are thought to lead to more efficient information processing, and thus to decreased time pressure, workload, and to improved performance. Now after reviewing the importance of developing good mental models, let's take a look at some common methods of capturing these internal structures.

### **Knowledge Elicitation Techniques / Findings**

Historically, many attempts have been made to pin point how experts use knowledge. Researchers have tried to design computer systems that are imitating the way human experts process information and solve problems. The research of Dreyfus and Dreyfus (1986) basically serves as a framework of the dynamic process of knowledge acquisition in studying machine intelligence. Their studies link knowledge engineering and expert systems to the knowledge acquisition process as they compare an expert system with intuitive expertise with respect to knowledge engineering. This research is attempting to analyze exactly how experts make decisions and come to their conclusions. This information is extracted in order to program computers to make similar decisions. The authors quote Feigenbaum, one of today's leading researchers in the knowledge engineering area:

“The matter that sets experts apart from beginners are symbolic, inferential, and rooted in experiential knowledge. Human experts have acquired their experience not only from explicit knowledge found in textbooks but also from experience...getting a feel for the problem” (Dreyfus & Dreyfus, 1986).

Since she already has the rules in his mind, the expert system builder only needs to extract them and program them into the computer. Perhaps this is easier said than



done. Socrates actually already tried to understand the elements of piety by characterizing heuristics in his time by asking a so-called expert to define the concept. The only response he got was examples from another philosopher's experience in this area. No straight set of rules could be identified. Today, Feigenbaum has attempted to be more specific with the help of knowledge engineering techniques. However, he too agrees that knowledge threatens to continue to be an unlimited number of special cases. Several different models have been devised in an attempt to capture the knowledge of an expert user.

### Measurement of Mental Models

One of these models originates from Oakhill and Garnham's (1996) research paper. A cognitive so-called GOMS, approach can represent the actions of an expert user in an attempt to predict user behavior. The model outlines the tasks performed by the user as she works through the goals, operations, methods, and selectional rules defined in this model (Card, Moran & Newell, 1983). In this approach, researchers timed and observed skilled users as they carried out an assigned task. The model is commonly used to predict expert, error-free performance. Although the model is not ideal for evaluating motivation and low-level tasks, it has been a useful tool for predicting and building models of human behavior. The predictions have helped to narrow down the design space by focusing on what systems are difficult to learn or use and in turn to find an alternate procedure. According to this idea, part of the limiting progress in contemporary artificial intelligence is due to the fact that experts can not explain exactly how they make judgements based on experience and arrive at solutions by intuition.

Calhoun, Roger-Adams, and Selvararay (1997) propose a survey method that uses several interview techniques to elicit data from subject matter experts (SME). The method suggested is referred to as the adaptive survey which is a combination of concept mapping, semi-structured interviews, questionnaires, and forums. According to the authors, concept mapping is a particularly valuable interview technique due to its attention getting, interactive informative and flexible nature. Concept mapping is a graphical technique that is based on free expression when attempting to capture expert knowledge. The concept mapping technique was done without the influence of interviewer bias. The concept mapping technique involves asking SMEs about information and asking them to formulate their answers in words/phases (concepts). These concepts are then drawn as maps that in turn result in a network of concepts called a concept map. It was found that the adaptive survey method worked well mainly due to its versatility. The concept mainly technique proved to be especially valuable when used in conjunction with other interview and non-pictorial methods. The concept mapping technique revealed user jargon and gave the interviewer a graphical overview of the information. The keywords used in the SME response were used to customize other interviews and any misinterpretations could be corrected immediately by the SME. Although the overall adaptive survey method was useful, the concept mapping technique indicated particular potential as it set the stage for high level of user interaction and revealed a lot of information in a short time.

That is what is going on in the knowledge engineering arena at the present. How to capture knowledge and mental models for the purpose other than designing an expert system is considered by Mogford (1991). He introduces the use of mental models

capturing in air traffic control. As we have already seen in previous research, a user's internal model of a system is very important when attempting to understand the human-machine relationship. Understanding the ATC controller's internal model could certainly help improve areas, such as human-machine interface, training and education issues. There are different methods to study mental models according to Mogford's work. Two of these methods mentioned are the inferential (indirect) and the verbal (direct) procedure. The author suggests that when the user has little discretion and the system constrains his opinions, the input/output can be measured with the indirect method. On the other hand, when involving higher levels of explicit manipulation, the cognitive process is more easily evaluated with the direct method.

It has been argued that the effectiveness of a user interface can be determined by how well it fits the operator's mental model. Recent studies indicate that there is a difference between highly qualified and average ATC workers when it comes to the spatial characteristics of their internal models. The findings indicate that the skilled group tends to use a presentation that is three-dimensional, whereas the less advanced group (trainees) uses a two-dimensional representation of the situation. The complexity of judgement increases with the skill level of ATC operators. The more experienced group also has better recall abilities as demonstrated at the end of a dynamic simulation task. The more experienced controllers were able to remember more aircraft information such as altitude and position than did the less experienced group. In other words, the quality of the internal presentation could be related to expertise level. To support this statement Mogford (1991) refers to a study conducted with Canadian controllers. The data from the study indicates that the ability to recall aircraft information from a dynamic

simulation is related to how well the controller trainee performs on the final simulation test in the ATC hiring program. The recall method could thus be useful for the evaluation of computer interface, screen organization, and various other computer aid design issues (Mogford, 1991).

More studies in air traffic control come from Boudes and Cellier's 1997 research regarding anticipation activity. In this study the controller anticipation range in a dynamic environment was evaluated through a verbal protocol. This work is based on the underlying concept/research on cognitive models and is an attempt to guide future work in the design of automated ATC tools. A dynamic environment is defined as being part of a spontaneous evolution where the system constantly is changing, regardless of the operator's actions. The controller in today's environment needs to project the information about the present situation and apply it to what the future state will look like. This projection is usually based on the typical behavior of the aircraft. Filtering is another activity that is commonly used by controllers to effectively handle the complexity of a particular situation. The authors refer to the work of Boudes and Cellier (1997) to explain the filtering process that revealed evidence that all the data for a flight is not processed in working memory. They introduce the idea of anticipation range in order to measure the elements considered in a particular situation by the controller. This idea is linked to the existing models of knowledge organization with the help of various schemas and semantic networks. The actual contraction of a mental model can be thought of as the activation of a network (nodes) and the reorganization of links between them (Boudes & Cellier, 1997). In the so-called anticipation range, these nodes are linked to the

elements in the ATC environment, such as aircraft, actions, and various other related ATC activities.

The experiment conducted by Bouldes and Cellier (1997) involved a simulated ATC scenario that compared the anticipation range of planning and radar controllers. Both groups had the same training and experience level. The purpose of the study was to identify if the anticipation range was different between the groups.

At the point of interruption in the ATC simulation the participants were interviewed separately with open-ended questions. A lexical analyzer was used to analyze the answers. The classification of the results clearly indicated a difference between the groups. The radar controllers' verbalization of their anticipation of a future development was focused on the traffic. The focus was on action verbs, whereas the planning controller tended to express verbs related to strip management. Also, the planning controllers' verbs leaned toward assisting the radar controller with his/her workload. As such, this study identified two different lexical categories, depending on type of controller being queried. In addition, the contextual lexical interpretation is a way to analyze the elements of a controller's anticipation range. By verbalizing the controller's anticipation of a future state we are able to gather data on the elements involved in anticipation. Basically, this lexical analysis demonstration allows us to parallel anticipation range to a symbolic, verbalized activity. In other words, what is verbalized is the mental model of a particular situation. They caution that this method is not adequate for evaluating the same thought process in a specific time interval.

## Situational Awareness

Mogford (1997) also links situational awareness and mental models in his article, “Mental Models and Situational Awareness in Air Traffic Control.” This paper reveals some interesting facts regarding the relationship between the mental model concept and situational awareness (SA). Controllers tend to form a mental picture of the task they are working with on the radar screen. The information they collect via communication and the radar screen is used to develop a mental picture of the airspace that is maintained to control air traffic effectively. This is commonly referred to as SA in human factors literature whereas a mental model is the organized knowledge that has depth and stability over time. The term model implies that a formation of a conceptual picture of the environment is used to understand and predict behavior of the system. The mental model in ATC is the underlying knowledge that is the basis for SA. In other words, the mental model is the basis for SA. Although the mental model is complex in its structure, and might not even be measurable, it is believed that data from auditory/visual displays are stored in SA and is used to update the mental model if there are long-term implications. Due to the similarities in knowledge elicitation techniques used to capture SA and mental models, research literature in this area is included.

Previous studies have indicated that the “picture” ATC controllers use are often a three-dimensional geographical presentation of the airspace. Studies along the same lines have also indicated that controllers with substantial experience have better recall of aircraft data than trainees. Experiments have been conducted which attempt to find a connection between recall of the picture and success rate in the ATC training facility. The procedure used in this particular experiment was to freeze the radar screen

unexpectedly and have the controller note (on a blank map) aircraft location, altitude, and identifier. The task was timed. This practice of freezing a dynamic simulation to assess SA has been widely used in ATC studies. Basically, findings suggest that SA may be an important attribute when it comes to ATC performance levels, especially when it comes to remembering altitude and heading information. It is noted throughout the literature that measuring mental models is very difficult, and based on current definitions of a complex knowledge structure, inaccessible to conscious exploration. On the other hand, SA, a dynamic and transient set of information supported on underlying mental models, has more potential as a measurement basis.

Similar techniques were the topic of discussion in a panel discussion at the Human Factors Annual Society meeting in 1992, in which Vidulich defined situational awareness as the capability to appropriately assess yourself, your system, and your environment in order to make the right decision at the right time. He presented three major approaches to effectively measure SA: the explicit, implicit, and the subjective rating system. The explicit method involves determining what contents are used from memory to analyze a particular situation. This can be done verbally (query) or spatially (by asking the participant to reconstruct a map). The implicit measures use the signal detection theory to figure out if the participant is sensitive to the critical elements in the situation presented. Lastly, the subjective rating system depends on asking the participant to rate her own SA during the situation. Vidulich (1992) conducted an experiment with air traffic controllers to test these three evaluation techniques. Basically, the participants were asked to monitor the movement of symbols with workload being altered by adding or subtracting targets. Vidulich found the different techniques seemed

to be useful in separate areas. For example, the memory probing technique (explicit) to locate targets was the best measurement of SA. Even though the explicit measure worked well to evaluate SA, it did not hold up as the number of targets increased. The implicit method on the other hand, was relatively independent of the increasing and decreasing of target numbers, but did show signs of being sensitive to the speed with which they were moving on the screen. The subjective rating system used in this experiment was the Situational Awareness Rating Technique (SART). He also suggested that according to the findings, the various sub-scales used in the SART method seemed to be more sensitive to experimental manipulations than a traditional single-scale subjective SA technique. This ties right into Endsley and Roger's (1996) study that they conducted to evaluate how air traffic controllers divide their attention. Two different measurement techniques were used: the Situation Assessment Through the Re-creation of incidents (SATORI) and the Situation Awareness Global Assessment Technique (SAGAT). The SATORI system was used to recreate operational errors on a graphical display and SAGAT was used to measure the understanding of the participant. As the SATORI system played the incident, the SAGAT technique was used as the simulation was frozen during the scenario. When the program was stopped, the controller was asked questions about the evolving situation. The screen went blank and the controller was asked to point out the aircraft on a map with only the navigational aids drawn out. Also, questions about the airplanes path, speed, and progression were asked. The subjects were then scored according to accuracy. The participant's perception of the current situation was then compared with the actual state.



Cooke (1997) from New Mexico State University proposes another method of assessing situational awareness. She holds that situational awareness has been both vaguely defined and inadequately measured. In Cooke's opinion, the current procedures of measuring SA fail to capture the complexity of cognition. Her paper presents the cognitive engineering approach as an alternative to measuring SA. This model emphasizes the elicitation of the cognition that is the basis for SA. Cooke refers to Endsley's explanation of individual SA. According to Endsley, the situational model is an individual's understanding of a situation at a particular point in time. This understanding plays a major role in the performance, judgements, and decisions a person makes in a certain situation. Cooke emphasizes that not only the feedback we get from performance is important when measuring SA, but also the cues and processes that resulted in that interpretation. This intermediate process is vital when it comes to training intervention or design. Current measures include query methods, performance based measures, subjective ratings, behavioral checklists, process measures, and knowledge elicitation measures. The cognitive engineering method presented in this paper incorporates cognitive and knowledge engineering methods. The proposed method of analyzing SA tends to concentrate on the elicitation of cognition as opposed to the traditional interest in the resulting performance. The method suggests comprehensive video analysis, structured interviews, and various conceptual methods to accurately evaluate cognition. The video records will be used to identify perceptual cues that lead to an action. In other words, we are not just interested in what the solution is, but also how the individual arrived at that solution. The interviews will differ from traditional queries in that they will help process tracing to reveal the contents of a person's situational

model. A major difference between these concepts is that the proposed model will pay more attention to the actual contents of the situational model as opposed to merely assessing it, as has traditionally been the case. Cooke suggests that the cognitive engineering approach has a potential future as a measurement tool of SA, as it covers the complexity of an individual's behavior better than other methods currently in use. She author alludes to the success cognitive engineering and knowledge elicitation has had in other areas and hopes that it can be applied to the methods of measuring SA.

Robertson and Endsley (1997) address the importance of developing a situational awareness program for aviation maintenance. SA is very important for the operation of complex environments. Aviation maintenance is an example of one such environment which are depended on to detect, assess and correct possible problems. The proper assessment of system states and the projection of their actions is all part of situational awareness. They suggest a breakdown in SA has been linked to airline safety issues.

Three levels of SA are discussed by Robertson and Endsley. When dealing with aircraft maintenance, level 1 SA, refers to mechanics' ability to be aware of the state of the system as a whole. Level 2 SA in turn is the mechanics' understanding and diagnosis of system malfunctions. The last stage 3 is the mechanics' ability to make projections of future state of the system based on their corrective actions. They point out that it is often difficult for a mechanic to project a future state due to little or no feedback. As a result, developing a complete mental model for making future projections is further complicated. Several training recommendations were suggested in this paper. It was detected that the communication between teams often was inadequate. The teams were unaware of the other teams' activities/goals. Since a clear picture of what needs to be

done, a shared mental model, is very important to maintain SA, a common frame of reference needs to be established. In addition, feedback on how well a particular diagnosis worked should be communicated to the mechanic. It was also suggested that either management or a computer could serve this purpose. People should be trained to provide feedback. This paper suggests that training to improve SA in aviation maintenance might reduce the number of occurrences linked to accidents and damage in aviation operation activities.

Rogers, Rutherford and Bibby (1992) describe some of the most common knowledge elicitation techniques used in human-machine design issues. When it comes to a way of measuring how people elicit information, the most common procedure is the thinking-aloud method. One must realize the limitations of this method that occur as a result of natural biases and incomplete information. In fact, they suggest that there is no best way of accurately measuring the models. Most experiments in this area are focused more on intuitive measurement methods than on formal procedures. There seems to be a gap between the concrete mathematical models and the less defined psychological version. There is a definite need for more research in this area to be able to establish a well-defined scientific method. One attempt to come up with a framework is to refer to the process an expert uses when solving a problem. The different stages a person goes through when solving a problem have been captured by verbal data and also in the standardized knowledge representation schemes found in artificial intelligence. However, when attempting to analyze raw data, it is difficult to consider all the social, psychological, and other factors that influence the decisions we make. The problem of data collection will remain, since the data represented is based on a chain of unquestioned

assumptions. The internal model is full of inconsistencies and lacks detail. For example, if asked about city locations in a country, it might be difficult to point out their exact location without ever seeing a map of the area. Lack of detail in the mental model reveals the inconsistency. The user is unable to express the inconsistencies since he often is unaware of the exact problem. The problem of identifying cities according to their orientation to north can only be accomplished if the right questions are asked.

Rove, Cooke, Neville and Schacherer (1992) also conducted a study of various mental model measurement techniques. Many different techniques have been used in the past and it is not yet clear how well each particular method actually pertains to similar results. In this experiment, knowledge elicitation techniques were used to compare mental models of both novices and experts. They found that mental models of an expert tend to be more complete than those of the novice. The study measured mental models that mechanics have of an automobile engine. Several different measurement techniques were used and one of them in particular supports the methodology of the present study. These techniques include; familiarity ratings, relatedness ratings, pathfinder, fault diagnosis rankings, and interviews. The familiarity ratings involve asking the participants to pair engine parts according to how they relate to each other. The relatedness ranking ranged from 1 = "highly related" to 6 = "unrelated." Fifteen randomly ordered parts and concepts of a car engine were presented. Next, the participants were asked to correct various faults that might occur in a traditional automobile engine. They were provided with a list of possible causes and then asked to rank them as the first, second, third thing they would inspect to correct the problem. In the interview process the participants were asked about possible engine trouble that they

were asked to fix. The mechanics were asked which part they would consider first and why. After the fault ranking task, the participants were to order different types of car engines. Eleven different engines were listed and the mechanics were to decide if each engine was a good example of the category it represented. Again, a rating system of 1 = “not typical” to 9 = “very typical” was used. Individual within-subject correlations were calculated on the relatedness ratings. Finally, within-subject correlations were grouped based on experience level to analyze differences between the reliability of experts and novices. Lastly, the participants were asked to explain the general theory of a car engine and its principle of operation.

In general, this indicates that each of these mental model measurement techniques tend to be reliable for both the expert and the novice group. In other words, the with-in subject correlations were statistically significant. The expert group tended to agree more with each other than the novices. The findings from this experiment suggest that mental models can be measured fairly reliably with experts showing a tendency towards more stability in their representations than novices as indicated by higher between-subject correlations. The different mental model capturing techniques revealed similar data, especially the relatedness ratings that indicated that experts have a deeper understanding of the car engine as they perceived the engine as two separate systems. One was the mechanical and the other one was the electrical system. Overall, the study suggests that each technique mentioned is useful. However, further research is needed to identify the strengths/weaknesses of each method.

Another variation of an interesting capturing method is to measure proficiency level. In the literature presented by Thompson, Jamieson, and Hendy, (1997), the mental

model content of a crew is assessed. According to the introduction statement, the key component of efficient decision making is dependent on the mental model held by the person or persons evaluated. The methodology used in this experiment to assess crew performance and differentiate between proficient and less proficient crews was based on recorded communication. The categorizing of proficient aircrews was based on the information collected from videotapes, an expert group's consensus, and by coding the communication that took place according to mental model categories. The communication that took place between the crew members during a simulator scenario might not be a complete picture of the mental model but is adequate to help evaluate the overall mental model. The communication that took place was coded according to the domain and function category they fitted in. The mental model domain refers to the thoughts an individual has pertaining to the flight. In this particular scenario the systems, checklists, geography, and the changing weather were the most important domains considered. The function category of the mental model measures the meaning of the communication. It ranges from basic awareness to cross checking to understanding the future implications of the crew's actions. The number of mental model domains during a flight are thought to be a measurement of the range of thought by an individual. In addition, systems knowledge, task prioritization, crew monitoring and open loop communication were also measured. Open-loop communication is the instances when no response is received from a crewmember query, indicating information overload. The experiment involved a time critical simulator scenario with system anomalies and threatening weather. As one might expect, the highly proficient crew (as agreed upon by experts viewing the videotapes on the scenarios) had more experience in the simulator

type used. Highly proficient crews demonstrated a greater depth of thought, as they tended to communicate pre-planning procedures, geography, and the goal of the overall mission. The more proficient crews also noted the change in wind direction more often than did the less proficient group. In general, the proficient group verbalized more of the mental model domains relevant to the flight scenario. Highly proficient crews consistently prioritized their tasks and indicated fewer open-ended communication situations where no response was received from their respective crewmembers. Less open-ended communication situations suggest more efficient information exchange and less workload. The less proficient crews spent more time focusing on checklists and rechecking procedures. Thompson, Jamieson and Hendy (1997) suggest that the measurement method presented here is reliable and is capable of supporting scientific data based on theory that can be applied to the aviation industry. In conclusion, the data from this study suggests the more proficient aircrews have more complete mental models, as they tend to be more dynamic decision-makers than novices are. This statement is based on the notion that they are quicker to identify aircraft problems and preplan the flight according to the problems presented with. The findings from this communication-based assessment of crew mental model content should be especially focused on when training future aircrews.

The purpose of Ricks, Jonsson and Roger's, (1994) study on cognitive representations was to research how pilots organize flight-deck information. A multi-dimensional scaling technique was used to analyze the underlying psychological dimensions or cognitive structures that pilots tend to apply to effectively organize information. During the experiment, the subjects were presented with 24 information

attributes that they were asked to rank and compare. A pair-wise comparison method was used where the participants had two information attributes on a computer screen they were asked to rate according to similarity. A scale of 1 to 9 was used, ranging from *very similar* to *very dissimilar*. The subjects entered their responses on a rating scale at the bottom of the screen. After completing the 24 attribute ratings, the task was to rank the attributes according to how important they were to managing flight-deck information. This time the attributes were presented on index cards and the position of the cards was recorded. A two-dimensional method was used.

The first dimension analyzed on a horizontal axis defined timeliness, urgency, and prominence on one side and quantity, confusing nature, and complexity on the other. This dimension refers to the content of the information presented. The second dimension defined compatibility and self-explanatory issues on one side and longevity, stability, and controllability on the other. This second dimension analyzed the perceptual attributes of the flight information presented. The terms on the index cards were ordered along a dimension from least desirable to most desirable display characteristics. This study focused mainly on interpreting how pilots mentally represent, prioritize, and assign importance to various flight-deck display characteristics.

Canas, Bajo and Gonzalvo (1994) evaluated mental model differences between novice and experts. An interesting point this paper brings up concerns the difference between novice/expert knowledge organization. This was traced with relatedness ratings that indicated that miss-defined concepts were more common in the novice group than in the expert group. As a result of this finding, they suggest that it is possible to assess a person's mental representation using recall, categorization, or relatedness judgements



because these tasks seem sensitive to changes in the mental models as the student learns a new program.

This study attempts to evaluate whether the mental representation of trace vs. non-trace trained participants differed significantly. In the study one group did use trace and one did not during their training in how to use C programming language. At the completion of the training, the participants were asked to assign ratings to pairs of concepts based on how related they thought they were on a scale from 0 to 9. The participants were also encouraged to work quickly. A distance matrix was used to analyze the data as the ratings were converted to distance by subtractions from nine. The weighted average procedure used here allows two types of data to be collected. One of these types presents the conceptual representation of the weight vector of each participant's matrix conceptual dimension.

The results show that the mental representation of C programming concepts did differ. The trace group tends to depend more on semantic dimensions whereas the non-Trace group used a syntactic one. What makes this finding interesting is that programming experts tend to organize concepts based on their meaning as did the trace group in this experiment. Therefore, the mental representation of the trace group had a close resemblance to those of an expert category. The study suggests that the use of graphical presentations in the training stage have an impact on how students organize concepts and that their mental picture seem to be more semantically inclined.

The main purpose of Cooke's (1994) study on knowledge elicitation techniques was to evaluate and summarize each method. She covers an array of different methods, but some of the most pertinent ones for this paper are the paired comparison, controlled

association, reference ranking, and some common sorting techniques. Paired comparison is a very popular method in which an expert subject is asked to assign a rating of relatedness to each concept presented with. The expert's judgement is recorded on a scale or movable marker. One major disadvantage with this method is that it is time-consuming, especially when very large samples are required. The pairs can be analyzed by  $(n(n-1)/2)$  with  $n$  being the individual concepts. Multidimensional scaling is another way of computing this kind of data. Another method better suited for fewer samples is the controlled association technique. In this procedure the expert is given one concept and asked to mention all other items that in his opinion are related to that particular concept. The reference ranking method requires each concept to be ranked as per similarity/preference by the participant. It is suggested that this method works best for homogeneous concept sets that can be ordered in one or more dimensions.

The last knowledge elicitation method we will cover from Cooke's (1994) paper is the sorting technique. The expert is asked to place the concepts in piles as they are related. The expert is asked to label the piles according to where he thinks they belong. This method is not very time-consuming, but at the same time is not very sensitive to variations since either the concepts are related or not. Another variation of this technique is the multidimensional sorting technique. This method allows the expert both to sort each card and to identify the dimensions which he thinks are appropriate labels for the sorted piles.

## **Relevant Design Issues for the Present Experiment**

With respect to design issues, Andre (1997) argues that cockpit designers need to use specific models of cognitive compatibility in order to optimize future cockpit interfaces. Further, he suggests that designers need to uncover new rules of cognitive compatibility and come up with a model to use in the design phase. Memory, perception, attention, mental models, and experience are all a part of the compatibility issue of a display. Spatial compatibility refers to the location of the display and how it corresponds to the location of the control. Andre refers to one of his studies that demonstrated that mental models and consistency across control pairs can be varied to be more compatible. In the study the participants were exposed to incompatible arrangements of controls and the upward movement of a stimulus was mapped to the lower of two response keys. In this experiment performance was degraded as a result of the control arrangements. However, when the participants were presented with a compatible mental model with the incompatible mapping of the controls revealed, performance was improved again. Compatibility is evaluated in three distinct phases: response tendencies, rules, and frames. The response tendency phase was compared to base compatibility rules that were mostly open-loop, meaning that they required little cognitive attention. The so-called rules, on the other hand, are performed on a cognitive level with clear procedures to follow. The frames are linked to higher-order cognitive processing, such as mental models that are applied when no clear procedures are available at the rule/response tendency level. Lastly, he mentions the evolution of design/evaluation of aircraft cockpit displays. Historically, the design process was reasonably straightforward with little or no

variation in the location of instruments. One reason for this was the inflexible nature of electro-mechanical displays. Today however, the new glass cockpits require more emphasis on cognitive compatibility rules, as they significantly will impact human performance. Andre suggests that a computational model should be implemented in the design process. This would make it easier for the designer to find the appropriate cognitive compatibility display control fit that will better predict the advantages of one particular display model.

Another interesting point when designing a display originates from Delzell, Johnson, and Liao's (1999) ideas. They suggest that this information is important so that a designer can match a display to the mental model and also so that the display can compensate for inconsistencies in a particular model. Basically, three models for this dynamic traffic scenario were introduced. Of these the spatial proximity model only takes current separation into consideration. The bearing model, which focuses on differences in closure rates, and the temporal model considers separation as a function of time.

The pilot's task in this study was to evaluate his freedom to maneuver based on other targets in the area. Also, a recall task was introduced as a distraction during the primary task. The purpose of this study was to determine which model pilots uses for different aircraft separation situations. The degree of freedom to maneuver was rated as very low to very high. In the recall task, altitude and heading was collected as measurement variables. The results indicate that pilots best remember targets that are close to them. Moreover, the participants tended to recall altitude better than heading. The mental model used tends to be a combination of the spatial and the relative bearing

model. The pilots' recall seems to be better when the target is in front of them than when presented behind or to the sides. The results suggest that pilots can not help but to pay attention to all aircraft close to them, even if they do not present a threat. It is suggested that display designers should attempt to get the pilots' attention only to the relevant aircraft information in the future displays introduced in the market place.

Fischer (1987) attempts to answer the question how mental models can be used to help users to take greater advantage of computer systems. He claims that in order for a system to be properly designed it must make it easy to form a mental model of that system. This means providing tools such as simplifying descriptions by using layers of abstractions, and to represent information in a structured sequence. Using these methods will increase the users cognitive ability to comprehend. Also, Fischer holds that most users do not care about internal or so-called "deep" knowledge as much as they do about achieving their goals. To make a system user friendly he lists a few important factors to consider when designing a complex system. These factors include using familiar representations that are based on previous knowledge, using the inherent strengths of human nature such as depending on the visual system (visualizing the model), and segmenting information into layers. These design techniques might aid the user when acquiring a mental model of a particular system. Lastly, it is noted that assessing the users exact mental model and understanding might be close to impossible. The development of good mental models is important when it comes to learning a new system.

## The Integrated Cockpit Information System

The ICIS is an attempt to integrate multiple flight information sources into one single display. The system was developed to possibly install a glass cockpit display to replace the cumbersome series of steps required with manual instruments presently utilized in the general aviation cockpit. This glass cockpit is also referred to as the multi-function display (MFD). The ICIS provides multiple layers, or so-called filters of information, applicable to a normal flight. The filters are all shown on the main screen and the pilot can access additional information regarding weather, geography, traffic, and airspace by selecting the individual items on the touch-screen display. When the user selects the weather filter for example, more detailed data pertinent to weather is displayed on the ICIS (wind, temperature, radar, dew point etc.). The display also allows the user to utilize the latest navigational devices for flight planning such as, re-routing and adding/deleting waypoints. A more detailed description is provided in appendix A.

The developers contend that grouping related flight information into filters might provide the user with metaphors that might improve the initial mental model development process of the system. With the use of schemas and suggested metaphors for flight information categories, designers have attempted to accommodate the user with a structured approach of presenting flight information. It is suggested that this particular ICIS format is organized according to basic cognitive theories that will provide the user with a picture of the overall situation. For example, the user does not have to depend on working memory to hold information but can rely on the display for problem solving alternatives. Thus, more resources for forward planning will be available and the need to develop an internal picture of the situation is eliminated. Moreover, the mental model

theory is also applied in this design format as the user is provided with structured flight information categories that are pertinent to a normal flight. As the mental model theory suggests, a novice user that is presented with a new problem might not know anything about alternative actions. The ICIS continually displays limited alternatives that can be easily accessed on the touch-screen display. The pilot is lead by the hand to the main category of applicable information and then into the next filter where more detailed flight information is displayed. This design technique allows the user to reach her sub-goals and subsequently to a solution of the overall problem situation. Based on these design techniques, the results of this study are assumed to reflect that the efficiency of the user is improved as a result of the structured graphical display format.

### **Summary of the Literature and Research Hypotheses**

Many different facets of the human problem solver must be considered. The literature provides a solid basis for linking knowledge organization with experience, with faster/more accurate response time, and lastly the development of a mental model of a system. As indicated in the literature, experience level, knowledge organization, and mental model development are all factors in the way people interact with a system and how they perform in a certain problem solving situation.

The first part of the literature review focused on the way people store knowledge. As indicated in the literature, people differ in the way they approach problems based on experience level and the way their knowledge is organized. Kahney (1986) suggests that people pay attention to different things as they advance through distinct learning stages and their thought process change. Dreyfus and Dreyfus (1986) refers to novices'

reasoning to be more concrete and rule dependent, whereas the experts tend to be able to utilize more abstract thinking patterns. Morris (1987) links this change in reasoning, as a result of experience, with reduced response time. Frederico (1995) agrees with this finding as he suggests that experts employ an outstanding organization of knowledge and as a result of having a structured/more organized knowledge base, are able to retrieve information faster, as well as perform with less errors than do novices in their domain. Ericsson and Chandler (1994), also support this study by stating that differences in expertise provide the largest and most reliable differences in performance between individuals.

The first part of this study is expected to support the findings from previous research that novice and expert pilots performance differ. Based on the review of the existing literature this study will test the following hypotheses:

H1: There is a significant difference between expert and novice pilots' performance.

To analyze the rankings of the test, this study employed a mental model measuring technique suggested by Rove, Cooke, Neville, and Schacherer (1992). The ranking methods have been used in prior research to pinpoint the differences in expert and novice reasoning. Individual within-subject correlations were calculated on various relatedness ratings. This procedure was also used in this study as it is suggested that it is one of the most reliable methods to evaluate both mental model differences between experts and novices and to investigate differences in knowledge organization as experience is gained (Canas, Bajo & Gonzalvo, 1994). These studies were used to develop the methodology of this study. The methods are explained in the next chapter.



This study addresses how people tend to develop a mental model as a result of experience. A mental model is often thought of as an image of objects and relations of a certain situation in one's mind which corresponds to objects and relations in the externally presented problem (Haynes, 1989). People compile knowledge with experience and subsequently form a mental model of a situation, based on what they have experienced in the past. Thus, as we gain experience in a certain situation, the mental model becomes more complete. Oakhill and Garnham (1996) indicate that as people make inferences about possible outcomes in a certain unfamiliar situation that they never have experienced before, the novice will not be able to effectively assess the situation based on their developed model. Along the same lines, the mental model theory suggests that one could limit the number of alternatives and make options explicit in order to improve novice performance. The above information attempts to explain how one could infer greater efficiency in processing as a result of having a more complete mental model.

The assumption was that the ICIS was very easy to use, regardless of experience level. Its highly organized interface provides the user with a display with multiple layers of information that can be assessed quickly in an orderly fashion. According to the literature, a novice needs more initial guidance in his problem solving process than the experienced person, and might benefit from the ICIS's layout. It is further suggested in the literature that working memory limitations should be a major consideration when designing new displays. The ICIS allows the novice user to depend on the layout to organize information as opposed to trying to hold separate pieces of flight related items in working memory as he attempts to solve a problem.

In sum, there is a clear indication that performance of a novice and an expert user do differ. However, based on the review of the literature, it is suggested that the establishment of mental models for pilots possibly could bridge the gap between novice and expert performance differences. Today's pilot display designers have attempted to employ an organized graphical format of information with explicit alternatives that is suggested by the literature to improve performance, regardless of experience level.

Therefore the second hypothesis to be tested is:

H2: Using the ICIS system, there will be no significant difference in the expert and novice pilots' performance.

## CHAPTER THREE: METHODOLOGY

### Participants

The theoretical population consisted entirely of pilots. The study sample were students at Embry-Riddle Aeronautical University who participated in the study on a volunteer basis. The subjects varied in age from 19 to 29 years old. All participants had flight experience as pilots. A total of twenty pilots were used and they were divided into two groups. A sample of ten flight students with a maximum of 100 flight hours were assigned to the “novice” group, while a sample of 10 flight instructors were assigned to the “expert” group. For the purpose of this experiment, the term expert is correlated with experience level. As mentioned by Endsley and Bolstad (1994), it is suggested that experience and training provide an individual with the ability to better cope with new tasks. In effect, the flight instructors who all belong to the expert group generally have gained more experience as they advanced through ERAU’s flight training programs and have accumulated more flight hours in the process. The more experienced group had between 500 to 2500 flight hours. The novice participants, on the other hand, were, at most, generally private pilots with a maximum of 100 flight hours and no instrument experience. Therefore, the novice participants had only a private pilot certificate, whereas the participants assigned to the expert group had a commercial instrument instructor license as well as a multi-engine license. The sample was 80 percent male and 20 percent female. The female participants were divided evenly into the expert and novice as two women were experts and two were novices.

## **Instruments**

The data from this study were gathered using a written test and a live performance test. The literature did not suggest the existence of standardized tests to measure the understanding and implied mental model among participants with varying experience level. Therefore, the author developed and pre-tested a three-part ranking test for this study.

A pilot study was conducted by a group of randomly selected students and instructors at Embry-Riddle's flight department. Five novice pilots and five experts participated in the pilot study. The scores were reviewed and modified to collect data relevant to this study. For example, flight scenarios were selected that were considered by the National Transportation Board as being associated with the leading factors in most general aviation accidents. When the study was initiated, the author selected five scenarios (terrain, weather, system failure, diversion and a traffic conflict). The pilot study revealed no difference in the way experts ranked flight items compared to novices in both the system failure and the diversion situation. Being that these two scenarios were not included in safety reports as major factors in accidents and the fact that the scenarios did not appear to be sensitive enough to detect any differences in the results, they were eliminated from the study. In addition, a time limit was added during the perception test in order to control for time variations during the test taking process.

## **Perception Instrument**

Before receiving the briefing on how to operate the ICIS, the pilots were given the perception test. The purpose of this task was to establish any differences between novice and expert pilots. The difference in their respective mental models was based on how the participants tended to prioritize pertinent flight information. Basically, three scenarios were presented to the pilots and they were asked to rate 20 flight items according to the importance of the scenario (see Appendix B). The pilots were instructed that the 20 flight related items on the list of items might or might not be related to the problem. The participants were told to rank highly related items with a 10 and items with no relevance to the scenario with a 0. The ratings were evaluated by how the experts differ in their problem-solving strategy compared to the novice group.

## **Procedure**

The first step in the study was to identify the participants from the candidate pool of flight student recruited from the ERAU flight department. The participants selected were asked to read and sign an initial briefing/informed consent form (see Appendix B).

The next step was to divide the participants into an expert and a novice group according to already discussed guidelines. Step three was to have all the participants complete the three ranking scenarios on the perception test. The participants were asked to rank twenty flight items according to how important they were in their opinion with respect to a terrain, weather and a traffic scenario. A total time of 15 minutes was allowed to complete the rankings.

The last part of the task was for the participants to partake in a brief overview on how to operate the multi function display (ICIS). Basically, the participants were given a short demonstration on how to access, select, and accept or cancel information on the display. Following the demonstration, each participant had about two minutes to familiarize his or herself with the different options on the display. The pilots were asked to evaluate and access information that were similar to the ones used in the written portion of the study. There was a terrain, weather, and a traffic alert announced verbally by the experimenter. The participants were given verbal instructions to find information regarding these three scenarios on the display as they were told: “You are concerned about possible high terrain in the next 30 miles. You are concerned about a convective activity in you flight path within the next 60 miles, and you are concerned about a traffic conflict. Please find the information on the display.” Each scenario was timed with a stop-watch and the number of selections on the display were counted on a scoring sheet by the experimenter.

A post hoc questionnaire was administered in order to further analyze the research findings. As already mentioned, the literature indicates that difficult scenarios are correlated with a significant difference in performance. This study was expected to support these findings that a task that is difficult to perform also reveals a greater difference in performance when comparing experts and novices. The variables compared in this study were analyzed with respect to significant difference in time, keystrokes and ranking scores on the perception test. The assumption is that since the results of the weather scenario indicated a significant difference in both the perception test and in the

ICIS performance scores, it would be logical to conclude that it was the most complicated scenario to solve.

The questionnaire presented the three scenarios (terrain, weather, traffic) and asked the pilot to rank each one according to difficulty level. The participant ranked each scenario on a scale from 1 (very easy) to 10 (very difficult) (see appendix C). The sum of the scores were simply added up to analyze the perceived difficulty level of each scenario. The questionnaire was given to 10 experts and 10 novice pilots at the Embry-Riddle flight line. Background and experience level of the participants were consistent with the participants used in the actual study. Thus, the expert group had more than 500 hours and the novice group were private pilots with less than 100 flight hours.

## CHAPTER FOUR: DATA ANALYSIS AND RESULTS

The data for the study was analyzed using SPSS 8.0 for Windows. Hypotheses H1 states that there is a difference between expert and novice pilots' performance. Any group differences will be determined based on the responses to the written perception scenario. Table 1 summarizes the results of the Wilcoxon Signed Ranks Test for Correlated Samples based on how the groups prioritized flight information.

Table 1 – Wilcoxon Signed Ranks Test

		N	Mean Rank	Sum of Ranks
Scenario 1 Terrain	Negative Ranks	5	5.40	27.00
	Positive Ranks	10	9.30	93.00
	Ties	5		
	Total	20		
Scenario 2 Weather	Negative Ranks	3	4.33	13.00
	Positive Ranks	10	7.80	78.00
	Ties	7		
	Total	20		
Scenario 3 Traffic	Negative Ranks	4	7.50	30.00
	Positive Ranks	8	6.00	48.00
	Ties	8		
	Total	20		

	Scenario 1	Scenario 2	Scenario 3
Z (based on neg. ranks)	-1.877	-2.282	-0.713
Asymp. Sig. (2-tailed) p-value	.061	.022	.476

The p-value for Scenarios 1 and 3 were .061 and .476, respectively. As these are greater than .05, there is insufficient evidence to conclude a difference in the way experts and novices prioritize flight information in response to the terrain and traffic scenarios; however, the p-value of terrain is 0.061 which is approaching significance.



The p-value for Scenario 2 was .022, which is less than .05. Thus, for the weather scenario it can be concluded that there are significant differences between the novice and the expert group.

H2 states that when using the ICIS system, there will be no significant difference in the expert and novice pilots' performance. Performance is based on time and keystrokes. Table 2 summarizes the results of Mann Whitney U Test for Independent Samples.

Table 2 – Mann Whitney U Test

		N	Mean Rank	Sum of Ranks
Scenario 1 Terrain	Expert	10	9.20	92.00
	Novice	10	11.80	118.00
	Total	20		
Scenario 2 Weather	Expert	10	7.15	71.50
	Novice	10	13.85	138.50
	Total	20		
Scenario 3 Traffic	Expert	10	7.85	78.50
	Novice	10	13.15	131.50
	Total	20		

	Scenario 1	Scenario 2	Scenario 3
Mann Whitney U	37.000	16.500	23.500
Wilcoxon W	92.000	71.500	78.500
Z	-.986	-2.535	-2.018
Asymp. Sig. (2-tailed) p-value	.324	.011	.044

The p-value for Scenario 1 was .324, which is greater than .05; thus there is no significant difference in the performance of novices and experts in using the ICIS display model for the terrain scenario. The p-value for Scenarios 2 and 3 were .011 and .044, respectively. Since they are less than .05, it can be concluded that there is a significant difference in the performance of novices and experts in using the ICIS display model for the weather and traffic scenarios.

The results of the post hoc analysis of the difficulty ranking questionnaire were as follows: the terrain, weather, and traffic scenario had the total scores of 66, 102 and 72, respectively.

As indicated by the scores, the weather scenario was consistently ranked as the most difficult scenario with a total score of 102. The traffic scenario was ranked as second with a total of 72, and lastly, the terrain was ranked as the least difficult with a total of 66. With these findings, it can be inferred that since the weather scenario took the most time and keystrokes, as well as ranked significantly different on the perception test, it was also the most difficult scenario. This assumption is consistent with the literature findings of the difficulty rankings from the questionnaire.

## CHAPTER FIVE: DISCUSSION

The results of this study indicate that experience level did have a significant effect on how pilots understand and prioritize information in selected flight related scenarios. Based on previous research, we assume that this difference can, in part, be attributed to experts having a more complete mental model as a result of having more experience. As indicated in the research of Kayuga, Chandler and Sweller (1998), experts tend to organize information in the form of hierarchically organized elements that are categorized according to the manner in which it will be used. Therefore, for the purpose of this study, the researcher developed a perception test which focused on prioritizing and ranking flight items that were used to establish this assumed knowledge organization difference between expert and novice test takers. Moreover, the literature suggests that the more difficult scenarios will be found where the differences in scores are more predominant.

H1 of this study states that there is a significant difference in the performance scores for novice and expert groups. This first hypothesis was supported with respect to the weather scenario. With the reported significant difference at  $p < 0.05$ , it is reasonable to conclude that performance scores for novice and experts are different when analyzing the results from the weather scenario. In other words, the experts clearly prioritized their actions differently than their novice counterparts. The reason for this significant difference could be attributed to the weather scenario being the most difficult task, therefore doing the best job of determining differences in rankings.

One interesting finding in this study was that some of the hypothesized differences that were suggested in the literature were not found. The p-values for the

terrain and traffic scenario ranking task were .061 and .476, respectively. Again, this could be attributed to difficulty level which will be discussed in the limitations sections. The ranking scores on the weather scenario indicate significant differences in the ranking scores; thus, a higher difficulty level could be inferred.

The hypothesis with respect to the interaction with the ICIS operation indicates performance of mixed results. The performance variables were based on time and the amount of keystrokes needed to successfully negotiate the scenarios. The reason for using performance as a variable is predicated in the literature of Ericsson and Chandler (1994). They indicate that differences in expertise provide the most reliable difference in performance between individuals. However, although it was suggested that the ICIS display model would alleviate some of these assumed differences, the hypothesis was not validated for all three scenarios; terrain, weather, and traffic. The p-value for the weather and the traffic scenario were .011 and .044, respectively. Since these results were both significant, one may conclude that, contrary to the expected results, there was a documented difference in the performance of novice and experts when operating the ICIS display model.

The p-value for the terrain scenario, however, was .324, which is greater than .05 indicating no difference in the performance of experts and novices when operating the ICIS display model. It has been further suggested by the literature that the use of schemas and metaphors tend to expedite the problem solving process and thereby may enhance the development of a mental model. Also noted in the literature, the cognitive load theory suggests that as a person gains experience, information can be processed in a more automated form and, subsequently, resources in working memory are available for

an improved problem solution. In this study it was assumed that the ICIS's highly structured organization of layered flight information on one display would provide equal reduction of working memory, regardless of the participants' level of expertise. As a result, both the experts group and the novice pilots would be more efficient in their problem solving process. The theory further assumes that learning primarily consists of the acquisition of automated schemas and that reducing the load on working memory should be the major consideration when designing a new information display and that the structure should facilitate schema acquisition (Kalyuga, Chandler & Sweller, 1998).

Novice pilots are often faced with the task of treating multiple sources of information in single elements as a result of not having them stored in long-term memory. This innovative technology was designed to simplify/organize tasks with the availability of a glass cockpit layout. In an attempt to revitalize the general aviation community, the new ICIS claimed to be both supporting and appealing to the general aviation public as it provides the user with many different sources of flight information on one single display. This results in the reduction of cognitive load and provides the user with applicable metaphors for mental model development. The metaphors are the filters for improved responses; e.g., weather, traffic, and terrain. It is now recognized that metaphors change over time but may be useful for building improved responses in the development of the initial mental picture. Metaphors provide guidance and serve as a useful response in the development of the mental model applied to cockpit situations.

These assumptions are only established with respect to the terrain scenario in this study. Although all the participants successfully completed assigned scenarios, it is indicated that the reduction of cognitive load might be especially effective in the terrain

scenario. The reason that the new display model's structured approach did not seem to be helpful in all three scenarios will be addressed in the limitations section.

The results of this study further report that novice and expert pilots differ significantly in the way they approached the weather scenario during both the written perception test portion of the study using conventional techniques, and during the operation of the ICIS model. Although the reason the weather scenario was significant in both hypotheses remains unclear, it is reasonable to link difficulty level with significant differences in novice and expert performance. As we are all aware, weather and weather forecasting is an inexact science and it requires both skill and experience to successfully negotiate these hazards. Another contributing factor that makes weather such a difficult scenario is that multiple sources of information must be retrieved and analyzed during a normal flight. However, when using the ICIS design, it was assumed that some of the cognitive load would be reduced as a result of having an integrated model that that would serve as a single source of updated graphical weather information.

This significance level is one of the most important findings in this study since weather related accidents are reported by the National Transportation Board as a major cause/factor in all general aviation accidents. More specifically, with pilot error being the leading cause of all fatal general aviation accidents, weather and terrain accidents make up for thirty-two and sixteen percent, respectively (NTSB, 1993). Although the results of this study only indicate that the ICIS model was helpful during the terrain scenario, the limitations of this study clearly indicate that more research is needed in order to reveal more conclusive results.

## CHAPTER SIX: RECOMMENDATIONS AND LIMITATIONS

One interesting finding in this study was that some of the hypothesized differences that were suggested in the literature were not found. The predictions for H1 stated that there would be no performance differences in performance for novices and expert pilots; however, the p-values for the terrain and traffic scenario ranking were .061 and .476, respectively, which did not support this prediction. One should keep in mind that one of the limitations of this study was that, due to the small sample size, the possibility exists of committing a Type II error (incorrectly stating no significant difference when, in fact, there was one). With a p-value of .061 the terrain scenario value is very close to the significant difference at 0.05, and there is a possibility that a Type II error was the determining factor. As a result, one recommendation is to test a larger sample in order for the data to reveal more conclusive results, especially with regards to the written portion of the terrain scenario.

With respect to the ICIS findings, only the terrain scenario supported the predicted results. Again, these findings could be linked to the performance measurements not being sensitive enough to evaluate the effect of the ICIS model.

As indicated in the literature, the more difficult a scenario, the more evident the differences in expert and novice performance. Therefore, it is reasonable to assume that since the participants in the novice group used more time and keystrokes to negotiate the weather scenario, it was also the most difficult task in this study. This finding would agree with the current accident findings for the general aviation public.

One important factor to consider with respect to this experiment is that the participants might not differ as much as they would from another university. If the

sample had been from the general population of novice and expert pilots, the results might have indicated different results.

Another caution and important recommendation resulting from this study is that future research similar to this should be conducted in a higher fidelity environment. In a “live” cockpit, the results of ICIS performance might be different than what was found in the conservative environment used in this study. Even though the research method chosen in this experiment did not reveal conclusive result in all the scenarios, a different operating environment might result in different findings. The data and operational experience from these efforts would reveal more conclusive results in the development and standardization of future cockpit technologies.



## REFERENCES

- AGATE Alliance Association, Inc.(1998). *The AGATE Flier*, 4(1):  
March Hampton, VA. <http://www.hq.nasa.gov/office.aero.oastthp/programs/avsaf/avsafpro.htm>
- Andre, D. Anthony. (1997). Cognitive Compatibility to Aircraft Systems Design and Evaluation. *The Journal of Human Factors and Ergonomics Society*, 39(1)  
New Mexico: Albuquerque.
- Boudes, N., Cellier, J. (1997). Evaluating the Concept of Anticipation Range in Air Traffic Control. *International Symposium on Aviation Psychology*, 9<sup>th</sup> Columbus, OH, April 27-May 1.
- Calhoun, S. C., Aleva. L. D. (1997). An Adaptive Survey Method: Multiple Interview Techniques In Dynamic Environments. *The Journal of Human Factors and Ergonomics Society* , 39(1) New Mexico: Albuquerque.
- Canas, J., Bajo, T., & Gonzalvo, P. (1994). Mental Models and Computer Programming. In: *International Journal of Human-Computer Studies*. B.R. Gaines (Ed.). New York: Academic press.
- Card, K. S., Moran, P. T., & Newell, A. (1983). *The Psychology of Human-Computer Interaction*. Hillsdale, New Jersey: Lawrence-Erlbaum Publishers.
- Cohen, S. M., & Thompson, B. B. (1999). Training Teams to Take Initiative: Critical Thinking in Novel Situations. Cognitive Technologies, Inc.: Virginia.
- Cooke, J. N. (1997). "Broadening the Measurement of Situational Awareness Through Cognitive Engineering Methods." *Human Factors and Ergonomics Society 41<sup>st</sup> Annual Meeting*. Albuquerque, NM.
- Cooke, J. N. (1994). Varieties of Knowledge Elicitation Techniques. *The International Journal of Human-Computer Studies*. 41: 801-849.
- Delzell Susanne, Johnson W. Walter, Min-Ju Liao. (1999). Pilot's Spatial Mental Models for Memory of Heading and Altitude. Mofett, CA.  
[cdti.arc.nasa.gov/delzellpaper.htm](http://cdti.arc.nasa.gov/delzellpaper.htm)
- Dreyfus, L. H., Dreyfus, E. S. (1986). *Mind Over Machine*. New York: MacMillan Inc.
- Endsley, M., Bolstad, C. (1994). Individual Differences in Pilot Situational Awareness. *The International Journal of Aviation Psychology*, 4 (1).

- Endsley, R. M., Rodgers, D. M. (1996). Attention Distribution and Situational Awareness in Air Traffic Control. *Proceedings of the Human Factors and Ergonomics 40<sup>th</sup> Annual Meeting*.
- Ericsson, K. A., Charness, N. (1994). Contemporary Approaches to the Study of Thinking and Problem Solving. *American Psychologist*. August, Vol 49(8): 725-747.
- Fischer, G. (1987). Mental Models A Computer Scientists Point of View. Department of Computer Science and Institute of Cognitive Science University of Boulder, Colorado.
- Frederico, P. (1995). Expert and Novice Recognition of Similar Situations. *Human Factors*, 37(1): 105-122.
- Haynes, R. J. (1989). *The Complete Problem Solver*. New Jersey: Lawrence Erlbaum Publishers.
- Hill, R., Levenhagen, M. (1995). Metaphors and Mental Models: Sensemaking and Sensegiving in Innovative and Entrepreneurial Activities. *Journal of Management*, 21(1).
- Huitt, W. (1992). Problem-Solving and Decision Making: Considerations of Individual Differences Using Myers-Briggs Type Indicator. *Journal of Psychological Type*, 24: 33-44.
- Johnson-Laird, N. P. (1995). *Human and Machine Thinking*. New Jersey: Lawrence Erlbaum Publishers.
- Kahney, H. (1986). *Problem Solving: A Cognitive Approach*. United Kingdom: Alden Press, Oxford.
- Kalyuga, S., Chandler, P., Sweller, J. (1998). Levels of Expertise and Instructional Design. *The Journal of Human Factors and Ergonomics Society*, 40(3).
- Kieras, D. (1999). *Mental Models for Engineered Systems and Computers*. Technical Communications Program University of Michigan. Work supported by the office of Naval Research under contract No. N00014-85-K-0138, NR 667 543.
- Morris, P. (1987). *Modelling Cognition*. New York: John Wiley & Sons.
- Mogford, H. R. (1991). Automation and Systems Issues. In: Wise, J.A., V.D. Hopkin, and M.L. Smith (Eds.). *Mental Models in Air Traffic Control*. Berlin: Springer-Verlag.

- Mogford, H. R. (1997). Mental Models and Situational Awareness in Air Traffic Control. *International Journal of Aviation Psychology*. Lawrence Erlbaum & Associates.
- National Transportation Safety Board. (1993). Washington, D.C. NTSB/ARG-95/01.
- Oakhill, J., Garnham, A. (1996). *Mental Models in Cognitive Science: Essays in Honour of Phil Johnson-Laird*. East Sussex, U.K. : Psychology Press.
- Redding, E. R., Cannon, R. J., & Lierman, B. (1991). Cognitive Task Analysis of Air Traffic Control. *Sixth International Symposium on Aviation Psychology*. Columbus, OH.
- Ricks, R. W., Jonsson, E. J., & Rogers, H. W. (1994). Cognitive Representations of Flight-Deck Information Attributes. *The international Journal of Aviation Psychology*, 4 (1) 65-83.
- Robertson, M. M., Endsley, R. M. (1997). Development of Situational Awareness Training Program for Aviation Maintenance. *Human Factors & Ergonomics Society 41<sup>st</sup> Annual Meeting*, NM,
- Rogers, Y., Rutherford, A., & Bibby, A. P. (1992). *Models In The Mind*. New York: Academic Press.
- Rowe, L. A., Cooke, J. N., Neville, J. K., & Schacherer, W. C. (1992) Mental Models of Mental Models: A Comparison of Mental Model Measurement Techniques. *Human Factors Society 36<sup>th</sup> Annual Meeting*, GA.
- Thompson, M. M., Jamieson, W. D., & Hendy, C. K. (1997). Assessing Mental Model Content and Function: A Metric of Effective Crew Performance. *Ninth Symposium on Aviation Psychology*.
- Vidulich, A. M. (1992). Situational Awareness: Modeling, Measurement, and Impacts. *Proceedings of the Human Factors Society 36<sup>th</sup> Annual Meeting*, Atlanta GA.
- Wilson, J., Rutherford, A. (1989). Mental Models: Theory and Application in Human Factors. *Human factors Journal*, 31: 617-635.

APPENDIX A  
MULTI FUNCTION DISPLAY

## ICIS DESCRIPTION

The multi function display used in this study was a visual touch-screen display of information needed for flight developed by Advanced Creations, Inc. The system contains extensive information about navigation and route planning, weather, geography, traffic, and airspace. The primary screen on the ICIS is the navigation screen that displays the options the pilot has from the various modes and filters. The primary navigation screen mainly is designed to help the pilot follow his progress through the flight. The active flight route is displayed with waypoints that change from blue to white once the pilot flies over them. An airplane shaped icon represents the aircraft and a box on the lower half of the screen shows up-to-date readout of the aircraft's heading and track. The track gives the pilot guidance instructions of what heading to steer in order to intercept the next current waypoint.

The main display on the ICIS is divided into modes, filters and function buttons. The modes are RE-PLAN, TRACK, and SCALE. These modes are ways to change and view your flight plan route and are located along the top section of the navigation screen. The filters are placed along the right side of the screen and are the TRAFFIC, WEATHER, AIRSPACE, and GEOGRAPHY. The filters enable the pilot to easily access additional flight information needed during a flight from a separate menu. Lastly, the so-called function buttons are always visible at the bottom of the navigation screen as they allows the pilot to ACCEPT or CANCEL the data selected. These options allow the pilot to delete or save alterations made in a mode or filter. All the modes and filters have additional menus that appear when their respective button is selected on the touch-screen display, except for the TRACK mode. The TRACK mode only allows the pilot to fly his

flight with north always being up (much like a traditional map) or to always display his aircraft with the heading he is tracking as the top of the screen.

To activate any of the other modes or filters options on the main navigation display, the user simply has to touch the desired button. For example, if the SCALE button is selected, it turns yellow (active) and an option of nine different nautical mile ranges are presented. The pilot can select a preset nautical mile range by touching the button and then touching ACCEPT on the button of the screen to return to the main navigation screen with the new range selected now being active. The ICIS touch-screen is suggested to be helpful in the mental model development process, and effective as the pilot has the ability to access a wealth of pertinent flight information directly on the screen. Basically, the RE-PLAN Mode allows the pilot to go directly to a waypoint, add a waypoint, delete a waypoint, trim a flight plan, or insert a waypoint into the current flight plan displayed on the screen. All these actions are performed by touching the desired destination and either hitting the CANCEL or ACCEPT button at the bottom of the screen. The WEATHER filter gives the pilot an option of selecting radar, lightning, freezing levels, flight conditions, wind, surface observation, forecast and route forecast weather along his route of flight. The GEOGRAPHY filter has the options of displaying terrain contours, roads, rivers, Towers etc. The TRAFFIC filter has the capability of showing all traffic, the traffic above, below, a data block of the traffic showing altitude and direction. When the pilot touches the AIRSPACE filter, he gets the options of seeing airports, nav aids, range rings (5 or 10 miles), latitude/longitude, and all information.

## ICIS HARDWARE

To conduct the experiment three system training testbeds were used (STTs). Here is the hardware listing of the STT.

### **STT1:**

Pentium II 233Mhz, 64MB RAM, 6.4 GB Hard Drive, Matrox Millenium II Graphics Board, Sound Blaster 16 Sound Card, 16X CDROM Drive, Teac 3.25" Floppy Drive Kingston PCI Network Card, 2 Speakers, Viewsonic 15" Monitor, PS-2 Mouse, Total of 2 Serial Com Ports.

### **STT2:**

Dual Pentium II 233Mhz, 64MB RAM, 6.4GB Hard Drive, Omnicomp 3Demon DTX, Graphics Card, Sound Blaster 16 Sound Card, 16X CDROM Drive, Teac 3.25" Floppy Drive, Kingston PCI Network Card, 2 Speakers, Viewsonic 15" Monitor, Dual Serial Port I/O Extender Card, PS-2 Mouse, Minimum of 4 Serial Com Ports.

### **STT3:**

Pentium 133Mhz, 32 MB RAM, 1.2GB Hard Drive, Diamond Stealth S3 Compatible Graphics Card, Sound Blaster 16 Sound Card, 16X CDROM Drive, Teac 3.25" Floppy Drive, Kingston PCI Network Card, 2 Speakers, Viewsonic 15" Monitor, PS-2 Mouse, 2 Serial Com Ports.

### **Miscellaneous:**

(4) Null Modem PC LapLink Serial Interface, (2) VGA Signal Splitter Cables, 10BaseT 5 Port Mini Hub, 10BaseT RJ-45 25ft Network Cables, (2) Liberty 12.1" 600x800 Flat Panel Monitors w/ELO resistive touch screen, Windows NT v4.0.

APPENDIX B

CONSENT FORM AND PILOT PERCEPTION TEST



## INFORMED CONCENT FORM

### AGATE MFD Study, Initial Briefing & Informed Consent Form

Thank you for providing your valuable time for the sake of future flight safety. The study we hope you will be helping us to conduct is on the cutting edge of 21 st. century technologies for General Aviation. It is obviously very important that that these technologies be thoroughly tested, and that tomorrow's pilots have the opportunity to help shape the new computer-driven cockpit display systems. You will be introduced to a new Multi-Functional display system that presents flight-path, color weather graphics and traffic alerts integrated into one display system, and you will be given the opportunity to try it out in a simulated flight scenario. Your assessments will be pooled with others to come up with some overall conclusions.

Before you can help us in this research, we have to ask for your "informed consent." This means that we have to tell you about the research, and especially about any risks to you from your involvement in the work. In fact, there are no drugs used or medical concerns in this study, and the flying is via simulation, so there are no foreseeable risks to you from participating in this research. You should not experience a feeling of workload or time pressure, certainly no more than you might on other training flights. In addition, your biographical data is confidential and for use by the research team only. No personal information will be passed along to university records, the FAA or any other third party. In the computerized analysis of the data, your information will be stored by your 'participant number' only (no names used). There will be no way of identifying your ratings or scores, or indeed any specific participant's scores, or questionnaire responses. In this study you are not being tested - you are doing the testing. You will be treated as a valued member of a team testing new equipment and technologies of the future of general aviation

If you have any additional questions about this experiment, please feel free to contact

**Susan Karkman**  
**(904) 254-7835**  
**Karkmans@db.erau.edu**

*I have read and fully understand the above information. I understand that my participation in this research is entirely voluntary, and that I may terminate my participation at any time without any adverse consequences to me.*

Print your full name:

Signature:

Date:

## PILOT PERCEPTION TEST

Name:  
Phone:

Date:  
Computer use a week (hours):

Flight time:

### Pilot perception test :

#### INSTRUCTIONS

Here are three different flight scenarios that we would like you to evaluate, based on the items listed below. You will be asked to complete two now and two at the end of the experiment.

The listed items below may or may not be relevant to the particular scenario you are presented with. In part A, assign all the items a value between 0 to 10 depending on how relevant you think they are to the scenario presented with. A value of 10 means that the item is completely relevant to the scenario, whereas a 0 would indicate an item to be of insignificant relevance. Several items can be assigned the same value. Evaluate each scenario separately. The test is timed and you have 15 minutes to complete the rankings. Good luck!

Here is the first scenario. Please assign the items below a value between 0-10 according to how important you think they are to this particular scenario (10=completely relevant and 0=insignificant relevance).

#### Scenario number 1:

You are concerned about a possible terrain conflict.

What are the most important items to consider?

Items:

1. Determine Current Position \_\_\_\_\_
2. Determine Location of Terrain \_\_\_\_\_
3. Determine Size of Terrain \_\_\_\_\_
4. Winds aloft \_\_\_\_\_
5. Radar update \_\_\_\_\_
6. Determine size of weather system \_\_\_\_\_
7. Determine location of traffic \_\_\_\_\_
8. Determine movement of traffic \_\_\_\_\_
9. Determine size of traffic \_\_\_\_\_
10. Refer to Sectional \_\_\_\_\_
11. Go-Direct to Alternate \_\_\_\_\_
12. Alter Flight Plan \_\_\_\_\_
13. Plot New Course \_\_\_\_\_
14. Locate Towers \_\_\_\_\_
15. Get closer to visually evaluate situation \_\_\_\_\_
16. New Airport/Navaid Selection \_\_\_\_\_
17. Determine Terrain Features \_\_\_\_\_
18. ATC Assistance \_\_\_\_\_
19. Surface Observations \_\_\_\_\_
20. Landmarks \_\_\_\_\_

**Scenario number 2:**

**You are concerned about thunderstorms along your route.**

**What are the most important items to consider?**

Items:

1. Determine Current Position \_\_\_\_\_
2. Determine Location of Terrain \_\_\_\_\_
3. Determine Size of Terrain \_\_\_\_\_
4. Winds aloft \_\_\_\_\_
5. Radar update \_\_\_\_\_
6. Determine size of weather system \_\_\_\_\_
7. Determine location of traffic \_\_\_\_\_
8. Determine movement of traffic \_\_\_\_\_
9. Determine size of traffic \_\_\_\_\_
10. Refer to Sectional \_\_\_\_\_
11. Go-Direct to Alternate \_\_\_\_\_
12. Alter Flight Plan \_\_\_\_\_
13. Plot New Course \_\_\_\_\_
14. Locate Towers \_\_\_\_\_
15. Get closer to visually evaluate situation \_\_\_\_\_
16. New Airport/Navaid Selection \_\_\_\_\_
17. Determine Terrain Features \_\_\_\_\_
18. ATC Assistance \_\_\_\_\_
19. Surface Observations \_\_\_\_\_
20. Landmarks \_\_\_\_\_

**Scenario number 3:**

**You are concerned about traffic in your vicinity,  
What are the most important items to consider?**

Items:

1. Determine Current Position \_\_\_\_\_
2. Determine Location of Terrain \_\_\_\_\_
3. Determine Size of Terrain \_\_\_\_\_
4. Winds aloft \_\_\_\_\_
5. Radar update \_\_\_\_\_
6. Determine size of weather system \_\_\_\_\_
7. Determine location of traffic \_\_\_\_\_
8. Determine movement of traffic \_\_\_\_\_
9. Determine size of traffic \_\_\_\_\_
10. Refer to Sectional \_\_\_\_\_
11. Go-Direct to Alternate \_\_\_\_\_
12. Alter Flight Plan \_\_\_\_\_
13. Plot New Course \_\_\_\_\_
14. Locate Towers \_\_\_\_\_
15. Get closer to visually evaluate situation \_\_\_\_\_
16. New Airport/Navaid Selection \_\_\_\_\_
17. Determine Terrain Features \_\_\_\_\_
18. ATC Assistance \_\_\_\_\_
19. Surface Observations \_\_\_\_\_
20. Landmarks \_\_\_\_\_

APPENDIX C

POST HOC

POST HOC

**DIFFICULTY RANKINGS SCENARIOS:**

Novice/Expert  
Date:

**Terrain Scenario**

Very Easy Very Difficult  
1 \_\_\_\_\_ 2 \_\_\_\_\_ 3 \_\_\_\_\_ 4 \_\_\_\_\_ 5 \_\_\_\_\_ 6 \_\_\_\_\_ 7 \_\_\_\_\_ 8 \_\_\_\_\_ 9 \_\_\_\_\_ 10

**Weather Scenario**

Very Easy Very Difficult  
1 \_\_\_\_\_ 2 \_\_\_\_\_ 3 \_\_\_\_\_ 4 \_\_\_\_\_ 5 \_\_\_\_\_ 6 \_\_\_\_\_ 7 \_\_\_\_\_ 8 \_\_\_\_\_ 9 \_\_\_\_\_ 10

**Traffic Scenario**

Very Easy Very Difficult  
1 \_\_\_\_\_ 2 \_\_\_\_\_ 3 \_\_\_\_\_ 4 \_\_\_\_\_ 5 \_\_\_\_\_ 6 \_\_\_\_\_ 7 \_\_\_\_\_ 8 \_\_\_\_\_ 9 \_\_\_\_\_ 10

Terrain: \_\_\_\_\_

Weather: \_\_\_\_\_

Traffic: \_\_\_\_\_