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# DEVELOPMENT OF THE SITUATION AWARENESS FLIGHT TRAINING AND SIMULATION EVALUATION (SAFTE) SYSTEM:

## II: FINAL DEVELOPMENT, INITIAL TEST, AND DOCUMENTATION OF THE SYSTEM

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1

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A technology has been developed for incorporating situation awareness (SA) measures into an inexpensive flight simulator. In this Phase II report, the final configuration of the simulator is described in detail, the first demonstration project to determine its training and psychometric characteristics is documented, and extensive hardware/software descriptions are provided. This Situation Awareness Flight Trainer Evaluator (SAFTE) system permits an experimenter to present operationally-relevant portions of aircraft missions in a laboratory, desk-top environment, while obtaining measures of the operator's SA embedded within the simulation. Measures of SA include spatial disorientation, awareness of aircraft present and predicted position, and several experimental metrics. In addition to the initial development, a modified SAFTE system was implemented into a human centrifuge at Brooks AFB to assess the impact of acceleration forces on pilot performance, and this development is described. Conclusions and recommendations concerning the further evolution of the SAFTE system include an assessment of the experimental SA metrics, addition of skill measures other than SA, and an evaluation of the value of this type of training for novice pilots.

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## PREFACE

# TABLE OF CONTENTS

## APPENDICES

# SECTION ONE

## INTRODUCTION

The issue of how to define "situation awareness"-- let alone how to measure it – has perplexed the scientific and operational communities for many years. In fact, General Merrill A. McPeak, former USAF Chief of Staff, has stated "...I know it when I see it..." but "Can it be measured objectively?..Can it be learned?" (letter, 17 July, 1991, SG/XO). This interest at the highest levels of command stems from the growing belief that situation awareness (SA) is a major contributor to both mission failure and accidents. Endsley (1988) cited SA as the most important factor in improving mission effectiveness. Hartell, Smith, and Prince (1991) reported that a lack of SA was given most often as the causal factor in 175 aircraft mishaps due to human error. Government, university and industry researchers have struggled to develop answers to General McPeak's questions, with some success. Generic definitions of this elusive construct have been developed, and specific measurement techniques with impressive power have been used. An off-line situation awareness test battery incorporating the best assessment techniques currently available has even been recommended.

Yet, the general consensus continues to reflect the opinion expressed by Shrestha, Prince, Baker, and Salas (1994) that "...there is no clear operational definition of situation awareness and an understanding of situation awareness is still largely incomplete." This attitude was apparent in papers presented at the "Second Annual Symposium and Exhibition on Situational Awareness in the Tactical Air Environment" at the Patuxant River Naval Air Station on June 3 and 4, 1997, and in a Navy Technical Report titled *Situational Awareness Guidelines*. In both of these, little attention is given to the definition or measurement of SA. Instead, there appears to be an implicit assumption that SA (whatever it is) would be enhanced by better information management and presentation. Thus, the focus of current efforts seems to have shifted toward attempts to improve performance, without addressing the underlying nature of the SA construct, or actually measuring it. In brief, at this time, while the construct of situation awareness can be described in conceptually satisfying terms, there is no well-defined **operational definition** of the construct. Without this, it is difficult to see how individual measures of SA will demonstrate the reliability and validity necessary for meaningful applications.

Beyond the question of an operational definition, there are even thornier issues involved in the development of a broader set of SA metrics than have been used in the past, and determining how to integrate these into a practical, dynamic simulation. Current measures, while showing reasonable validity (Fracker, 1991a), have been criticized because some are limited to retrievable short-term memory, and others do not take into consideration the dynamic nature of the SA environment (Sarter and Woods, 1991). This latter point is especially troubling to those attempting to develop metrics of SA useable to the military community. If laboratory studies yield results that are not translatable to the dynamic operational environment, their isolated "validity" might lead to erroneous conclusions and catastrophic system designs.

A need was therefore recognized to address three general areas: 1) the development of a defensible, theory-based operational definition of SA, 2) the development of an expanded set of SA metrics, and 3) the development of a dynamic simulation capability into which the SA metrics can be embedded.

The present report describes the results of a Small Business Innovation Research program

(Phases I and II) designed to address these goals. A brief review of the literature on situation awareness has been presented in the Phase I final report on this project (O'Donnell, Eddy, Cardenas, Trafton, and Campbell, 1995), and will not be repeated here. The Phase I effort also involved development of a proposed cognitive-model-based definition of SA, and this is repeated below, since it forms the basis of a series of proposed SA measures that were implemented and evaluated in Phase II. These range from awareness of simple spatial location and environmental surroundings to the existence of complex cognitive schemas. The final design and implementation of a low-cost, desk-top flight simulator with a realistic aerodynamic flight model was then carried out, and this development is described in detail below. This simulation, along with its embedded SA measures, has been termed the Situation Awareness Flight Training Evaluator (SAFTE).

Finally, an implementation demonstration designed to yield initial data on the SAFTE system was carried out, and is documented in Section Five. Obviously, for any complex construct such as SA, any vehicle purporting to assess it will have to undergo years of testing and modification before rigid scientific criteria can be met. Questions of reliability, validity, stability, and sensitivity can only be answered in any final sense by a large number of studies, independently replicated. However, the initial demonstration provides at least a preliminary database that will allow researchers to develop appropriate experimental designs. While it would be unrealistic to believe that all psychometric questions could be answered within this effort, the demonstration described in the appendix to this report should provide an initial foundation on which further research on the SAFTE system can be carried out.

# SECTION TWO

## DEFINING SITUATION AWARENESS

Operation of today's complex aircraft requires almost super-human levels of performance sophistication on the part of the pilot and crew. Over the years, engineering developments continually made manual control of the aircraft _easier_ (although the degree of _precision_ in manual control has not decreased). At the same time, however, levels of cognitive complexity required to carry out key flight operations increased dramatically. In effect, what began as a relatively precise manual task has evolved into an extremely complex cognitive and information processing task, while not significantly reducing the requirements for control precision. Essentially, in highly complex operations (e.g., fighter aircraft) the physical demands have not been reduced, even as the workload and information processing requirements have increased.

It is not surprising, therefore, that the questions to be addressed by the training and human factors communities have similarly become more complex. Simple manual control issues have now been replaced by concerns about complex constructs that have proven difficult even to define, let alone to measure. Workload, confidence level, and decision making are but a few of these complex constructs. They have the essential characteristic of being multiply-determined entities which generate or "emerge" from a complicated interaction among many individual factors.

Among such emergent constructs, the concept of "situation awareness" (referred to as "SA" in the remainder of this report) has perhaps received the greatest amount of recent attention, and has proven to be one of the most difficult constructs to capture empirically. As indicated by General McPeak, most individuals feel that they intuitively understand SA. At an elementary level, it is felt to be a _consciousness_ that one has about immediate surroundings and immediate tasks at hand. However, even the most superficial reflection reveals that this notion is inadequate. Large components of what is intuitively considered to be SA are simply not "conscious" in any traditionally defined way. In the skilled performer, many factors which permit the individual to respond to the present environment appropriately (e.g., the ability to access mental models in long-term memory, or the ability to project _future_ contingencies based on present and past environments) are seldom reflected in focal consciousness.

In view of this, any attempt to define SA must encompass more than simple focal consciousness concepts. In the past, the many attempts to define SA have had a great deal of difficulty including all of the various levels and factors of this complex construct, at least in ways that led to objective measures. Representative definitions are reviewed below. For more complete reviews, beyond the scope of this report, see Shrestha _et al_ (1994) and Dominguez (1994).

### Representative Definitions of Situation Awareness

One way of classifying definitions of SA could be based on whether the focus of the definition was on the single pilot or on a crew. Taking the crew interaction approach, Bolman (1979) referred to SA as the _crew's_ theory of the situation. Bolman placed great emphasis on the ability of each crewmember to generate "theories" (or, in more current terminology, mental models), and then to test them through interaction with other crewmembers, while confronting and managing conflicts. Schwartz (1990) also defined SA in terms of the perception of "factors and conditions" which affect the aircraft and the crew over a defined period.

7

Orasanu (1990) also took a group approach to understanding SA, embedding the construct into a decision-making paradigm. This author proposed that groups must utilize certain "supporting cognitive components" to make decisions. These included situation assessment, metacognition, shared mental models, and resource management. The component of situation assessment was defined as the interpretation and appreciation of cues important to the recognition of a problem requiring decision or action. The actual definition of SA, then, involved the crew's sensitivity to these cues. With this orientation, measures of SA could be developed based on the types of communication among crewmembers. In fact, communications-based measurement of SA in the multi-crew environment, along with rating scales and peer evaluation, appear to be the currently popular approaches (e.g., Mosier and Chidester, 1991; Brannick, Prince, and Salas, 1992; Shrestha et al, 1994).

Definitions of SA which focus exclusively on the single-pilot situation tend to lean more toward the individual's "knowledge", and thus tend to be consistent with current terminology in cognitive psychology. For instance, Harwood, Barnett, and Wickens (1988) defined SA as the pilot's knowledge of a dynamically changing situation. Four elements were seen as comprising that knowledge: 1) Where -- location of objects and spatial relations among them; 2) What -- presence of objects and of system states; 3) Who -- the command structure; and 4) When -- mission events along a time continuum, including prediction of future events.

Using the cognitive orientation proposed by Rasmussen (1986), a more specialized definition of SA has been proposed by Kass, Herschler, and Companion (1990). They defined SA as "...skilled behavior that is the ability to extract, integrate, assess, and act upon task relevant information." (Shrestha et al, 1994). They emphasized the point that highly skilled behavior is based on the acquisition and implementation of patterns of response, rather than on traditional stimulus-response (S-R) approaches.

Perhaps the most popular current definitions of SA have been inspired by the work of Endsley (1989) and Fracker (1988; 1989). Endsley (1991) defines SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the future". A model of SA developed by Endsley (1991) allows three basic levels or depths of SA: 1) observation, 2) integration, and 3) projection of events into the future. The first level -- observation -- involves a recognized sensory input that is stored through iconic and echoic memory. The conglomerate of these observations is then processed into an overall picture of the environment in the integration stage. The third stage, projection, involves anticipation of the outcomes of the integration carried out during the second stage.

Endsley (1989) also enters into extensive consideration of the types of cognitive processing that are carried out at various levels of SA. For instance, the relevance of incoming sensory information may be compared to previous experience, and may trigger more focused attention on particular aspects of the environment. Fracker (1988) emphasizes this focus. Activities are intimately tied to working memory which, in turn, may be related to long term memory stores involving more complex and automatic reactions (schemas). In Endsley's view (1989; 1991) the actual mechanisms of SA are intimately tied to the quality and quantity of schemas available to the individual in long term memory. If appropriate schemas are available for the environmental and task demands, short-term memory can be off-loaded, and the individual's workload is substantially reduced. If appropriate schemas are not available, processing will need to be carried out in working memory, which will then become heavily loaded.

The work of Endsley and Fracker appears to have influenced a popular definition of SA which is

directly relevant to the flight environment. This views SA as "a pilot's continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission and the ability to forecast, then execute tasks based on that perception." This definition has been widely reported and used by the operational community in the Air Force (McMillan, 1994).

One of the more comprehensive recent explorations of SA has been provided by Vidulich, Dominguez, Vogel, and McMillan (1994). They distinguish between process and product in SA definitions. Extraction of information from the environment, integration of information into an overall mental picture, and anticipation of future events are emphasized in the SA definition (Dominguez, 1994, p.11). The overall approach appears to divide SA into four cognitive activities: 1) extracting information from the environment; 2) integrating this information with relevant internal knowledge to create a mental picture of the current situation; 3) using this picture to direct further exploration in a continual perceptual cycle, and 4) using this information to anticipate future events. With this breakdown of the SA construct, Vidulich et al (1994) have taken a major step toward incorporating several aspects of existing SA definitions into one that encompasses both the process and product of SA.

Toward an Operational Definition of SA

In spite of some obvious differences in the SA definitions reviewed above, there are some common elements (as pointed out by Dominguez, 1994) which might serve to generate a consensus. Most obviously, current concepts of SA go far beyond any simple notion that it consists of the individual's conscious "awareness". Most current definitions have included concepts related to working memory, long term memory, mental models, and schemata. Another common thread implied by most current definitions is that SA can differentially exist on several levels or depths of operation. However these levels are defined, there appears to be a trend toward understanding that SA may involve different types or stages of information processing. At the broadest level of definition, these stages are divided between working memory and long term memory. The general concensus is that if the more working memory is involved in maintaining SA, the workload will be higher. A critical implication of this aspect of the definition is that SA will have to be measured multi-dimensionally. No single "holy grail" assessment technique will be sufficient. Finally, the work of Sarter and Woods (1991), as well as others, suggest that SA must be viewed as a dynamic process that must be assessed as an "embedded" construct in the context of actual simulations.

It appears from the above discussion that any definition of SA broad enough to encompass the many varieties and complexities of the construct would have a great deal of difficulty being operationally defined. In fact, as noted above, Shrestha et al (1994) have concluded that even with all of these varied definitions of SA, no operational definition currently exists. "Operational" in this context refers to the fact that theoretical concepts such as "knowledge of ...", "perception of ...", or even "awareness of ..." are used to define the construct, without themselves being defined in measurable, observable terms. While such approaches certainly assist in understanding the nature of SA, and may help bound the overall concept, they fail to suggest (let alone mandate) specific measurement approaches that would make assessment of SA objective.

The goal of the present effort, therefore, was first to develop an operational definition of SA which would suggest a specific set of measurement approaches. A starting point for such operational definition was the relative agreement among scientists that SA can differentially exist on several levels or stages of processing. It was hypothesized from this that an operational

9

definition could be formulated in terms of different types or levels of information processing carried out by the operator.

As each of the current definitions were examined, it became clear that they address levels or "depth" of information processing components such as sensory registration, perceptual organization and other functions within working memory, long-term memory, and even highly overlearned, automated responses. It appears reasonable, therefore, to select or focus on such information processing stages as the potential operational definition of SA. Each of these stages has been studied empirically, yielding not only a great deal of information about the stage itself, but also about possible techniques which can be used to measure the individual stage. If, therefore, SA can be conceptualized in terms of the level or depth of information processing, there is a significant potential that it could be measured objectively.

An implication of this approach is that, because SA is so complex, it can not be measured by a simple, uni-dimensional "magic" measure. Instead, the construct should be approached from the view that it consists of multiple levels or types of cognitive processes, which combine to produce the final performance. Measurement of the SA construct will therefore involve probes of many or all of these processes. The observable "measure" of SA, then, will be the degree to which the person can demonstrate, through a required performance, that each cognitive process is capable of being utilized. Ultimately, these measures could then be used to produce a cognitive "profile" that describes that individual's level of SA.

Stated most succinctly, it is proposed that an appropriate operational definition of SA is:

> *The types or levels of information processing performance demonstrated by a particular individual under a given set of environmental and task/goal demands.*

In other words, it is suggested that metrics of SA must be tied to the capability of the individual to perform well within a given task/goal demand situation, where these tasks or goals can be objectively related to the level of information processing required by that situation.

The above definition, while somewhat more specific, is not a radical departure from previous approaches. It is consistent, for instance, with the approach of Sarter and Woods (1991), at least in the sense that it requires a dynamic environment be used to test the total concept of SA. All measurement, we would propose, must be made within the context of this dynamic environment.

Indeed, an important observation by Sarter and Woods (1991) pointed the way to making this definition truly operational, and set the stage for subsequent developments in the present effort. These authors point out that in traditional cognitive terms, a "mental model" does not, in itself, constitute SA. Traditionally, mental models refer to an individual's representation of a small piece of the world in which they find themselves. For example, in the game of tic-tac-toe a person represents the game with two pairs of crossed lines, Xs, Os, rules of play, and concepts of winning configurations.

Situation awareness, on the other hand, is viewed as an open, dynamic system that involves the interplay of several mental models (the plane, its trajectory through space, the enemy's plane and it's potential flight path, the weapon systems of each, etc.). While mental models might be a prerequisite for certain types of SA, their existence does not constitute SA. This view focuses attention on the fact that the actual assessment of SA must be tied to a demonstration that the

individual is capable of <u>utilizing</u> mental models or schemas in a given situation. In other words, it is not sufficient to simply know <u>what</u> to do in a given situation; if the pilot lacks the <u>ability</u> to perform that action, then no SA can be said to occur. The key here is that an observable, measurable behavior should be required from the operator in order to determine that a certain level or type of SA exists.

This recognition led naturally to investigation of existing and novel assessment techniques that could probe various levels of information processing. These investigations are described in the next section.

# SECTION THREE

## SITUATION AWARENESS MEASUREMENT TECHNIQUES

### Existing SA Measurement Techniques

Although many techniques have been used to probe for what has been called "SA", relatively few have been used for more than one or two situations, or have been tied directly to a theoretical foundation. Fracker (1991) has reviewed SA measures extensively, and his classification forms the foundation of the discussion presented below. Fracker divided SA measures into three broad categories: subjective measures, explicit measures, and implicit measures. Representative samples of each of these types are described below.

#### Subjective measures

Subjective measures nominally require the subject to rate either global SA, or constructs believed to underlie SA. A widely used subjective scale was developed by Taylor (1989), and is called the Situation Awareness Rating Technique (SART). Three factors relating to SA were identified through principal component analysis: attentional demand, attentional supply, and situational understanding. Although it has been pointed out that this type of assessment confounds workload with SA, it has proven valuable in some situations. Other subjective scales have been reported, utilizing information-theoretic approaches (Amburn, 1994) or other techniques.

A particularly well-conceptualized approach to measuring SA subjectively has been presented by Pew, Adams, and Tenney (1991). These authors first made a cogent distinction between the process of SA acquisition, and the actual awareness resulting from that process. Paralleling this concept, they suggest two different approaches to measuring SA. One is dedicated to isolating the process itself, and involves having the crew "think aloud" during or after a mission. This think aloud protocol is then analyzed. The second approach involves examining the crew's performance on selected missions to determine retrospectively what the SA was. In the specific, the authors recommended three particular measures. The first one involves computer modeling of aircrew performance. This model is then compared to an actual simulation of the same performance in order to isolate the knowledge, procedures, and data used by the crew in achieving their performance. The second technique proposed by Pew et al. (1991) involves inserting erroneous or anomalous information into a scenario and measuring the time that it takes for the operator to recognize the unusual information. The hypothesis is that if the operator is using a particular mental model, this detection time will assess the quality of the model. The third approach involves presenting unexpected situations to the operator, and assessing the time that it takes to alter the original operating plan or mental model of the person. These approaches, though promising, do not appear to have been applied in actual SA measurement contexts, although they have been used in other contexts.

#### Explicit measures

Explicit measures, as discussed by Fracker (1991), can be divided into two categories: retrospective measures and memory probes. Retrospective measures involve questioning a subject who has completed a mission or mission segment with respect to relevant items that should have been noted during the performance. They represent, therefore, a short-term memory probe with some time delay involved. The second type of explicit measure has gained

widespread popularity and, in so far as anything has been standardized in the SA literature, has become an accepted standard. The "probe techniques" described by Endsley (1988) involves exposing the subject to a particular scenario and, at carefully selected points, "blanking" the scenario. The scenario is stopped, or salient information is removed from the screen. The subject is then questioned concerning the information in order to determine whether he or she was "aware" of it.

Two sub-categories of this latter approach have been used. In one, the subject is directly questioned about the occurrence of an event. In the other, the subject is asked to replace or indicate where a missing object should be placed. Endsley (1991) suggests that the former "questioning" technique may be appropriate for determining the "what" question - that is, whether or not the subject recognized that an event had occurred or that a particular target was present. The second "replacement" technique is particularly appropriate for measuring error in the subject's SA. Since it is possible to calculate the difference between the actual position of the probed object and the replacement position, interval-scaled measures of error can be obtained with the replacement technique.

While the two probe techniques have been perhaps the most widely used approaches to assessment of SA, there have been some disturbing problems reported. Fracker (1991) reports that some probe techniques appear to be reliable while others are not. No extensive study of validity of these approaches has been carried out. Fracker points out that probe techniques are still after-the-fact determinations. As such, they still suffer the potential problem of a discrepancy between what actually happened during the mission performance, and what the subject reconstructs during the probe itself.

Implicit measures

Implicit measures of SA involve projection of current and past events to future conditions. In essence, the operator is required to respond to specific questions dealing with the occurrence or nonoccurrence of events or objects, particularly future events (Endsley, 1991) or about the "envelope" of the enemy's operation (Fracker, 1991). Fracker has also pointed out that utilization of implicit measures necessitates some constraints on the overall variability of options in the real situation. As such, it is pointed out that implicit measures of SA may not represent an adequate or complete range of conditions for a given situation.

Integrated SA measures

Implicit and explicit measures can be integrated into a single technique, as reported by Endsley (1987; 1988; 1990). The Situation Awareness Global Assessment Technique (SAGAT) blanks the simulation at some random point, and presents a series of questions intended to reflect the operator's SA requirements and knowledge. These questions are randomly taken from a larger set of questions, and a composite SAGAT score is then developed by comparing the subject's answers to the real situation. Endsley maintains that the SAGAT provides a highly face valid global measure of SA which is objective, and which reflects the instantaneous condition of the operator.

However, Sarter and Woods (1991) criticized the SAGAT technique as being intrusive, and as prompting specific, static information which will differ in essential ways from that which would actually be experienced in the dynamic flight situation. These authors believe that memory probe measures in general tap a limited aspect of the overall SA construct. In fact, they

maintain that any post-hoc data collection will fail to tap (and may even distort) unconscious processes that were actually present during the task performance. Sarter and Woods (1991) suggest that SA can only be assessed in the context of a complex, dynamic simulation which has been specifically developed to probe well-defined SA issues. In other words, scenarios must be developed which span a range of situations, from those with low level requirements, to those presenting complex interacting situations. They suggest that "...by embedding specific tasks that tap knowledge of the different dimensions of situation awareness, it is possible to determine what specific information the pilot must be aware of at a particular time."

### SA Measures Incorporated Into the Situation Awareness Flight Trainer and Evaluation (SAFTE) System

A meeting was convened at Brooks AFB in May 1995, to consider the SA measures that had been recommended during Phase I of this effort (O'Donnell, Eddy, *et al*, 1995). NTI scientists and programmers, along with pilot consultants and Government representatives, attended this meeting. Each candidate SA metric was discussed from several viewpoints. The rationale for including it in the original recommendations was presented and evaluated. If the rationale was considered defensible, practical issues of how the measure could be obtained were then suggested and evaluated. Programming difficulty was considered as part of this evaluation. Finally, a consensus decision on whether the measure should actually be included in the SAFTE system was made.

In line with the SA definition proposed above, the general orientation in selecting SA metrics was to include a range of techniques that probed as many information processing components as possible. Further, the original concept of SAFTE was to develop a set of metrics that could be "embedded" into the flight simulations. These metrics were conceptualized as relatively discrete measures, each of which would contribute a different kind of information about the individual's SA at the time of measurement. They would then provide a multi-dimensional description of the person's state of SA (which, after all, is a multiply determined construct). This description would be based on which capabilities he or she can demonstrate, and the degree to which each one is demonstrated. In other words, the intent was to provide a measurement tool that is able to define the profile of an individual's SA.

In practice, SA assessment within the SAFTE system consists of a set of flight scenarios, during which multiple SA probes are employed. The combination of probe performances on which the subject performed adequately defines his or her level of SA for that type of environment and situation. The actual considerations and measures incorporated into the SAFTE system are described below.

## SA MEASURE #1. ENVIRONMENTAL STATUS AWARENESS

### Rationale for the Measure

Virtually all information-processing theories agree that appropriate registration of sensory conditions provides the basic foundation for later processing. In the case of SA metrics, this must be taken to include not only basic sensory registration, but some level of conscious awareness of the sensory environment. Stated most simplistically, this level of SA processing says that the person must be taking in the relevant aspects of the environment and, at some level must be "aware" of that environment. This is similar to what Endsley (1990) describes as "level 1" situation awareness.

14

Operationally, this type of awareness is critical in a variety of situations. Most notably, in an air-to-air combat situation, the pilot must often engage one bandit with "focal" attention, while still processing the general position, number, and movement of others. When the first engagement is completed, the pilot must be able to know the approximate location of the next bandit to be engaged. This is the type of SA that will be probed by the first SA metric.

In the present case, it is proposed that this type of SA incorporates processing beyond the iconic and echoic stages in that some degree of "awareness" must be present. It should be noted that this awareness need not be in the forefront of consciousness. Rather, the criterion established for this type of awareness is simply that the information is retrievable. In other words, either simultaneously with its occurrence or subsequently, the person can remember and report the information concerning the immediate environment.

## Approach to Measuring Environmental Status Awareness

In terms of this type of awareness, it is hypothesized that the person should be able to report on the existence of significant aspects of the environment. The goal here is simply to determine whether the person is able to retrieve sensory input information from short-term memory. No attempt is made to elicit precise location information or complex interpretation of the data, and no projection into the future is required. Thus, this level of probe is intended simply to measure the person's range of "awareness" of the environmental conditions. Such "awareness" is typically probed either with retrospective or concurrent "explicit" measures of SA (Fracker, 1991). Because there is some controversy concerning whether retrospective (after-the-mission) measures confound momentary and reflective SA, the concurrent measurement approach was incorporated into the SAFTE system, as described below.

As a further refinement of this type of measure, Eubanks and Killeen (1983) and Amburn (1994) have suggested that the probe be structured with "yes-no" responses in order to permit information-theoretic analyses. In effect, since each response reflects a "positive hit" (a correct yes answer), a "negative hit" (a correct no answer), a "positive miss" (an incorrect no answer), or "false alarm" (an incorrect yes answer), the data lend themselves to a 2-by-2 matrix. From this, following Kantowitz & Sorkin (1983), the sensitivity of the subject (d') can be calculated for the given experimental condition. In other words, standard information theoretic measures can be calculated. If desired, even entire receiver-operating-characteristic (ROC) curves could be determined for a series of experimental conditions to account for other sources of variance than SA. The "sensitivity" of the operator reflects his or her ability to detect an environmental condition. Fracker (1991) recommends this approach as "...an empirical and an intuitively reasonable measure of awareness for a particular kind of event". The SAFTE system therefore collects all data in this measure (and others described below) in the form of questions that can either be answered "yes" or "no". The individual user can then decide whether to simply calculate percent correct, or to apply the information theoretic approach.

## SAFTE's Technique for Measuring Environmental Status Awareness

The technique used in SAFTE for this and some later SA measures is one generally referred to as the "freeze", "memory probe", or "blanking" approach (Fracker, 1991; Endsley, 1994). In this, the screen of the simulator goes blank, either at defined mission times or specific mission events. A short question appears on the screen asking for specific information about whether certain conditions were or were not present at the time of the blanking. The information

requested simply involves whether a given situation, event, or object was present or not. Although general information about the location of an object might be requested, no precise localization is requested (as will be done in later measures). Examples of questions that were used in the demonstration project (see Section Five) are provided below, and the full list of questions used is given in the Appendix 7.

> - At 900 MSL, ask: "YOU ARE NOW ABOVE 800 FEET".
> - At 9 min. into the mission, ask: "YOU ARE LESS THAN 8 MINUTES INTO THIS MISSION."
> - At 5 NM from the target, ask: "YOU SHOULD SELECT AB NOW!"
> - PRIOR TO WP #1, ask: "YOU SHOULD HAVE ALREADY SELECTED AIR-TO-AIR MODE."
> - During an early portion of the SECOND "outbound" leg of a Combat Air Patrol (CAP) mission, ask: "YOU ARE NOW ON AN OUTBOUND LEG OF THE CAP PATTERN."
> - Within 5 seconds after the first launch of a MRM on a bomber, ask: "THERE IS NO SAM SITE TARGETING YOU AT THIS TIME."

In any particular use, the questions to be asked will depend totally on the scenarios being used by the experimenter or trainer. Therefore the SAFTE software provides a simple way to generate and insert new questions into either the "canned" scenarios or into those generated by the user. However, the sets of questions used in the demonstration project can also be used as they exist in the delivered SAFTE product. In other words, the system is robust enough to permit researchers a great deal of freedom in such choices.

## SA MEASURE #2. AWARENESS OF FUTURE ACTIONS

### Rationale for the Measure

The next type of SA measure also uses the blanking technique proposed by Endsley (1994), and described under SA MEASURE #1 above. In this case, the questions asked of the operator during the blanked period do not simply refer to the presence or absence of an environmental condition, but rather request information about an activity to be carried out in the future. In other words, the operator is not simply queried about whether an object or condition exists, but is asked to anticipate an event or condition that will happen later.

Although this and the previously described measure appear to share a great deal in common, it is argued that they actually measure different levels of SA. At very least, responding correctly to questions involving future action requires an ability to "project" events based on current conditions. Thus, it would appear that this type of awareness requires considerably more working memory capacity than simply reporting whether the object or condition was present. In practical terms, this type of probe should be operationally relevant in those situations where the individual might become pre-occupied with the current task to the extent that future actions are jeopardized.

## Approach to Measuring Awareness of Future Actions

The actual measurement of this level of SA is virtually identical to that described for SA Measure #1. The only difference is that questions probe what the pilot has been instructed to do in the future. In selecting such questions, a major consideration should be the activity that is going on when the question is asked. At the simplest level, the question could ask when the next turn should be initiated while the aircraft is in straight and level flight (low activity). A more challenging type of question would involve asking about a turn that might be required while the aircraft is ascending or descending (moderate activity). An extreme challenge would be to ask a question while the pilot was in the middle of a pop-up bomb delivery (high activity).

## SAFTE's Technique for Measuring Awareness of Future Actions

The SAFTE system measures awareness of future actions with examples of each of the above types of questions. In all of the procedures, the screen is blanked, and a question is posed on the screen. The question requires the operator to give "yes-no" answers. As described above, these answers can be analyzed as percent correct, or with information theoretic techniques. Examples used in the demonstration study are given below, with the complete list presented in Appendix 7.

- At 15,000 MSL, ask: "YOU ARE TO LEVEL OFF AT 20,000 FT."
- Immediately after WP2 has been entered, ask: "YOUR NEXT ALTITUDE CHANGE WILL BE TO GO TO 600 MSL."
- At 9:45 min. into the mission, ask: "AFTER YOU REACH WP3, YOU SHOULD DESCEND TO 540 MSL."
- Immediately after subject begins the pull-down maneuver in a pop-up bomb attack, ask: "YOUR FINAL RELEASE ALTITUDE SHOULD BE 10,000 MSL."
- If altitude goes below 7,800 MSL, ask: "YOU SHOULD PICKLE AS SOON AS THE PIPPER REACHES THE TARGET."
- At 5 NM prior to WP 5, ask: "YOUR NEXT TASK WILL BE TO TURN TO WP 5 AND MAINTAIN ALTITUDE."

## SA MEASURE # 3. AWARENESS OF INTEGRATED/PROJECTED INFORMATION

### Rationale for the Measure

This level of SA encompasses the subject's ability to report considerably more dynamic aspects of the stimulus environment than simple existence of objects, conditions or programmed future action. Specifically, the probes in this measure are designed to determine whether the person is capable of reporting information that is "derivative" in nature. In this context, the term "derivative" is defined as requiring the integration of a number of sensory/perceptual elements into a hypothesis about a present or future state of the environment. In other words, this level of SA results in "information" (or a belief) that a state exists, or is about to occur, in the environment which cannot be confirmed by the information available in the environment at this moment in time. It is an extrapolation or inference based not only on the data immediately available, but also on what has gone on previously, and the operator's expectations about what will go on in the future.

## Approach to Measuring Integrated/Projected Information Awareness

The general concept of this level of SA is based on the assumption that the pilot, at various levels of SA, progresses from a simple awareness of "what is" or "what will be", to "what might be". In the previous assessment techniques, probes have determined whether the person knows that certain environmental objects exist, and what he or she is supposed to do in the future. In the present level of SA, the probe is directed to determining whether the pilot knows what future conditions will exist given what is happening *now*. In other words, given certain assumptions, what will my present state cause to happen in the future? At this stage, interest is in whether the pilot can predict these future events at a relatively simplistic level.

From a conceptual viewpoint, this level of SA requires the pilot not only to "know" where relevant elements of the environment are (recognizing that these may not be in the forefront of consciousness), but also to integrate immediate past experience (the angular movements of own and enemy aircraft) and present position, and then to project these into a future state. It should be noted that this level of SA requires somewhat more sophisticated "training" of the person, over and above basic flying skills, in the sense that it requires that the person have extensive experience with the specific predictions unique to the flight environment.

## SAFTE's Techniques for Measuring Integrated/Projected Information Awareness

Two types of questions were used under this general level of SA: specific event projections, and more complex "derivative" event projections. The first type is similar to the "projection" probes described by Endsley (1991b). These are blanking techniques that are administered in the same way as the other blanking techniques incorporated in SA Measures 1 and 2 above. In this case, however, the probe questions deal with projections of specific events into the future. This presumably goes beyond any of the types of probe described above. The goal here is to identify a class of complex predictive constructs that underlined pilots use in deciding how to operate the aircraft. It is still relatively primitive in the sense that it involves working memory to a very large (not necessarily exclusive) extent. In effect, this class consists of complex inferences by the pilot, based on the immediate past and the pilot's expectations about his or her own behavior, and which could be verbally reported during or shortly after the event.

The second category of question under this general technique involves a more complex derivative awareness by the pilot. Interviews with the pilot consultants revealed that there are certain cognitive "bases of flight operations" which are critical to combat success. A prime example of such a basis can be termed "perception of the enemy's plane of operation." In air-to-air combat, it is critical to maintain awareness of the plane described by the enemy aircraft's current linear momentum (Shaw, 1985). In effect, in a dynamic engagement between aircraft, the "horizontal" plane, which is normally represented by the earth's horizon, changes every time an enemy aircraft makes a maneuver (and the pursuit aircraft responds to that maneuver). At one moment, the enemy may be flying or turning in a plane that is completely parallel to the horizon. In the next instant, the enemy may enter a diving turn in which the plane of operation now changes to a 45-degree angle relative to the horizon. It is incumbent on the pilot to be aware of the enemy's plane of operation at all times in order to carry out a responsive maneuver.

In terms of cognitive theory, these types of "awareness" involves a complex synthesis of several individual kinds of present and past information which are integrated at a very high (late)

level of working memory. For example, in determining a "plane of operation", the pilot must perceive a motion vector of the enemy aircraft for some period of time, consider the present tactical situation, and project this into a probable plane of motion of the enemy in the immediate future. The integration of these separate activities must be carried out (and appear to the experienced pilot) as a single percept. For this reason, probe techniques that assess the individual's ability and current capability to maintain this type of awareness represent a different level of SA than those discussed previously.

Examples of these types of question used in the demonstration study include the following:

- At 9:15 minutes into the mission, ask: "YOU SHOULD HAVE LESS THAN 1 MINUTE LEFT BEFORE ARRIVING AT WP3."
- While the pilot is following the flight director, ask: "THE FLIGHT DIRECTOR APPEARS TO BE GIVING FALSE INFORMATION."
- During ascent (at any point) ask: "ROLLING LEFT IS THE QUICKEST WAY TO BRING THE TARGET VERTICAL RELATIVE TO THE HUD."
- When aircraft is 3 min. from WP3, ask: "YOU HAVE TRAVELED MORE THAN HALF THE DISTANCE BETWEEN WP2 AND WP3."
- When aircraft has turned 15 deg., ask: "YOU ARE AT LEAST HALFWAY THROUGH YOUR REQUIRED TURN."

Other general examples of questions that could be generated in these categories are fuel management, armament selection, and projections of future threat configurations. Probe questions (or even measured flight responses) which tap these various kinds of information obviously will be appropriate for different kinds and portions of missions. A representative sampling of these data should provide a comprehensive indication of the pilot's ability to maintain this level of SA.

## SA MEASURE #4. SPATIAL ORIENTATION/DISORIENTATION

### Rationale for the Measure

Gillingham (1992) and many operational pilots have stated that one of the basic causes of a loss of SA is spatial disorientation (SD). In a most fundamental sense, the foundation for SA in the aircraft is that the pilot knows how the craft is positioned and moving with respect to the earth. If this basic awareness does not exist (at least in normal flight situations) it is unlikely that more complex situations will be clearly apprehended. Spatial disorientation is, in fact, defined as the "erroneous sense of one's position and motion relative to the plane of the earth's surface" (Gillingham, 1992). This, of course, is directly related to the above discussion of derivative event projection, except that it refers to perception of one's self, rather than of an outside entity. It appears, then, that one of the most basic measures of the pilot's SA should be to determine whether the aircraft's position and motion are correctly perceived.

### Approach to Measuring Spatial Orientation/Disorientation

In flight, orientation is maintained by monitoring information from the flight instruments. Angular positions are bank, pitch, and heading. The corresponding angular velocities are the rates of roll, pitch, and turn (yaw). Altitude is the linear position parameter; and airspeed, slip/skid rate, and vertical velocity are the linear velocity parameters. Given the

above, it can be concluded simply that spatial orientation is nothing more than the correct awareness of the control and performance flight parameters. Any measure of spatial orientation then becomes a function based on the ability to determine how well the subject maintains desired performance. For instance, if the pilot is required to accomplish a task which demands maintenance of airspeed, and all other distracters are removed, then the pilot can be said to be spatially disoriented when airspeed consistently deviates outside of an accepted tolerance for normal performance (e.g., +/- 10 knots). Maintenance of precise airspeed by a trained pilot is a direct reflection of awareness in this case.

## SAFTE's Techniques for Measuring Spatial Orientation/Disorientation

Since there are no accepted standard ways to measure SD as an index of SA, methods which have been developed to assess the effects of variations in flight symbology on flight performance were adapted to the present use. These techniques have been described in detail by Weinstein and Ercoline (1991), and have been used in high fidelity simulators and in actual flight. Specifically, SD is measured in two ways.

A. Precision instrument control task.

In the first technique, termed the "precision instrument control task", aircraft performance is measured against pre-briefed performance characteristics (airspeed, altitude, etc.) in those situations where these can be defined. This is accomplished by determining the root-mean-square (RMS) error of those flight parameters required for a given mission. The subject is briefed that minimum deviations about a "target" flight parameter are the desired outcome. He/She must then apply normal instrument crosscheck procedures to integrate all the needed information to minimize deviations.

Traditionally, this method has been used where one flight parameter is of interest or when each flight parameter is treated independently of the others. Only recently have attempts been made to determine the effect one parameter has on another. When dealing with a complex construct such as SA, of course, these interactive effects will be of great interest to the experimenter. The capability, within the SAFTE system, to record many flight parameters and store them in a readily accessible way (see below), will facilitate many types of investigations using this SA Metric.

B. Unusual attitude recovery.

In this procedure, the pilot is taught a procedure prior to testing which is unique to one of four classes of spatial orientation:

1 UA Number 1. If presented with a nose high situation, the pilot must confirm that the unusual attitude exists, then initiate a stick and throttle input dependent upon the bank. If the display depicts an inverted bank (>90 degrees), then the pilot is to adjust power to maintain airspeed, roll to a completely inverted bank (avoiding negative G-forces), and pull the nose toward the horizon. Once oriented close to a wings level, inverted attitude, the pilot is to roll the aircraft upright (e.g., within +/- 8 degrees of pitch and +/- 5 degrees of bank).

20

2) UA Number 2. Given the same nose high situation, but with the bank less than 90 degrees, the pilot is to either maintain the bank (allowing the nose to drop toward the horizon) or increase bank toward an inverted position, while maintaining positive G-forces. Recovery is complete when the aircraft is upright and in the same orientation as described in 1) above.

3) UA Number 3. If the pilot sees an orientation that is nose down and less than 90 degrees of bank, the correct recovery procedure is to roll in the shortest direction toward an upright condition while pulling the nose up and adjusting the power as necessary. Recovery is defined as above.

4) UA Number 4. If there is a nose down condition, and the bank is greater than 90 degrees, the pilot must not pull the nose up until the bank is less than 90 degrees. Again, recovery is defined as above.

The data collection procedures for these two techniques are reasonably straightforward within SAFTE. The precision instrument control task involves simply defining the flight parameters of interest for a given mission scenario, and then briefing the pilot to maintain that set of parameters. This can be made as complexes as desired by introducing distracters during the mission, in order to determine whether the pilot can maintain spatial orientation. The researcher will define analyses (either the standard RMS error provided by SAFTE or other statistics).

For the unusual attitude recovery task in SAFTE, the aircraft is presented in one of the above-defined unstable orientations after a screen blanking or freeze (as described above for SA MEASURES 1, 2, or 3). This simulates an event that could have occurred, for example, during a "blackout" or short period of loss-of-consciousness (LOC). In other words, the subject will have just been probed about some external condition while the screen was "blanked". After responding, the simulation re-appears. However, the aircraft may be in one of the unusual attitudes described above. Dependent measures include time to initial stick input, accuracy of stick input (per AFM 51-37), and total time to recovery.

## SA MEASURE #5. MINIMUM INFORMATION REQUIREMENT

### Rationale for the Measure

Most definitions of SA imply that specific kinds of information are being processed (while others are not) at any point. The thrust of the entire present approach, in fact, is to operationally define SA in terms of this distinction. It is proposed that a person's SA can be described by determining what information the pilot is capable of processing. While it is desirable to have metrics that probe specific types of information processing defined by the investigator, it is also desirable to include measures which allow the subject to reveal what types of information he or she requires to carry out the task. In other words, instead of asking pre-defined questions, these metrics should reveal whatever information requirements exist for an individual at a given time.

### Approaches to Measuring Information Requirements/Processing

The first four measurement categories proposed above attempt to arrive at decisions about specific types of information processing by relatively indirect means. The present measurement category approaches the same task with a more global and direct set of methods.

21

The subject is asked directly to indicate, through behavior, what information is required at any point. From these behavioral responses, it should be possible to determine what the subject's "mental model" was (in a global sense). This conceptualization of a "mental model" is somewhat broader than some previous definitions. It includes not only explicit or implicit "awareness" of the present static situation, but also the dynamic situation. The subject is not only modeling the static environment, but is making behavioral decisions based on projections and hypotheses of "what is going to happen" in the future. Thus, this measure attempts to tap the strategies (deeper cognitive activities) being used to translate present information into performance.

## Recommended Techniques for Measuring Information Requirements/Processing

Two relatively different techniques for assessing the person's global "mental model" are possible in the SAFTE system. The first, directly related to the work of Pew, Adams, and Tenney (1991) and others, involves subjectively addressing the subject's awareness and actions through protocol analysis. Although this capability currently exists in SAFTE, it was not included in the demonstration project, on the premise that its application is so mission-specific that any resulting data would be unusable to subsequent investigators. The second technique, described below, attempts to infer the subject's mental model through explicit behavioral measures.

### Minimum Information Flying

This technique is adapted from experimental approaches used by several investigators, particularly in driving studies, which permit the subject to determine and demonstrate how much information is necessary to maintain performance. To our knowledge, this technique has never been suggested as an SA measure. In a typical driving study, the subject drove an automobile in traffic, while wearing a pair of occluding goggles. Whenever the subject felt that additional information was required in order to drive safely, he or she was permitted to open up the occluding goggles, which were normally closed. The subject was instructed to minimize the time the goggles were open, consistent with safety.

Considering the dynamics of this performance, it would appear that a subject's decision to open or close the goggles is the result of an interaction among several factors. Among these, obviously, the complexity and demands of the situation form the foundation. However, the subject's understanding of the situation, the ability to project the present situation into the future, the individual's self-perceived skill level to handle the projected environment, and a variety of motivational factors probably also influence decisions. Many of these factors, of course, appear in many definitions of situational awareness. Therefore, it would seem appropriate to develop an "occlusion technique" which could be used to assess SA.

Given the relatively standardized protocols provided by the SAFTE system, it was not difficult to adapt previous techniques in driving studies to the SAFTE system. Of course, in the present context, goggles were not necessary. Instead, in the SAFTE system, the individual is able to control whether or not the display is on the computer screen. The person is instructed that a certain portion of the mission is to be flown with "minimal information" consistent with safety and/or mission accomplishment. The computer records the time and events occurring during those periods in which the individual sought information, and in which the screen was occluded or blank. Given that the protocols have been developed specifically to demand certain kinds of awareness from the person, the basic outcome of these measures indicates the presence

or absence of such awareness.

Since the minimum information flying approach to SA has never been previously used in such a simulation, certainly not in the military context, a great deal of study must be carried out before it can reach the level of parametric and statistical confidence enjoyed by other measures in the SAFTE system. A considerable amount of creativity was necessary to design research protocols and flight scenarios that yield specific information about the subject's SA. In addition, in later studies, considerable work will be required to assure that extraneous contributors to the dependent measures are identified (e.g., training effects, motivation, etc.). On the other hand, it does appear that this approach, precisely because it may capture a number of such additional determinants, may be particularly useful in assessing an individual's state of training. In fact, it might, in itself, have considerable training value as the individual learns what information is really critical for adequate performance. In this sense, it may be the ideal training vehicle for increasing an individual's SA.

Since this is a new attempt to measure situation awareness, specific approaches to analyses require considerable innovation. During the demonstration study, various approaches were considered, ranging from those that could be objectively "scored" to those that approached "clinical interpretation". The basic dimensions of several of these approaches are mentioned briefly here.

1) For a given "maneuver" (e.g., a turn, a long segment of straight and level flight, a pop-up, etc.) there are a certain number of information "bits" that are essential. Without these, the human (or a machine) simply cannot achieve the mission's goals. If subject matter experts can identify these, then a quantitative comparison between this minimum required information and that requested by the subject could be calculated. Too little requested information suggests underestimation of data and/or overconfidence, while too much requested information suggests poor levels of training, underconfidence, or other motivational factors.

2) When a subject switches the display "off", it could be assumed that he or she believes that little or nothing is going to happen in the immediate future requiring complex or visually directed action. From such actions, it should be possible to hypothesize what the subject's "mental model' of the situation was at that time, and even the data (awareness) the subject had of preceding and current situations.

3) A simple measure of effective "situation awareness" could be obtained by simply looking at a ratio of the amount of time the display was turned off versus the accuracy of flight and the success of the mission. Clearly, there will be a trade-off -- too much time with the display off will certainly result in poorer mission performance. Too little time may indicate lower SA capability (among other things).

This may be the most creative and innovative measure in the SAFTE system. Hopefully, it will reveal aspects of SA that have never before been probed. However, as a new measure, it will require considerable further investigation to determine the best, most valid, and most reliable approaches to analysis of the data. In the demonstration project for this study, a few of these analysis approaches were attempted, but for reasons explained in Section Five, no extensive analyses were carried out.

# SA MEASURE # 6.  SCHEMA ACQUISITION AND DEMONSTRATION

### Rationale for the Measure

The final set of measures that were included in the SAFTE system involves the development of complex responses based on over-learned stimulus-response relationships. Various authors have discussed such general response sequences under the heading of automaticity, scripts, or schemas (Chase and Simon, 1974; Chi, Feltovich, and Glaser, 1981; DeGroot, 1966).  Again, for the present purposes, it is not necessary to create fine distinctions or become immersed in theoretical discussions concerning the differences or levels of depth among these various conceptualizations.

The overall concept of this type of SA is seen most readily in skilled performance.  There is a continuum of skills that is clearly recognized in training.  Once the individual reaches a level of performance generally considered to be acceptable and safe, he or she is already demonstrating behaviors that are radically different from those of the trainee.  While the novice explores possibilities sequentially and frequently considering alternatives that are clearly inappropriate, the skilled performer appears to operate more holistically.  A complex situation is responded to as a whole.  In such cases, the skilled performer may not even be aware (at a truly conscious level) of the elements making up the whole.

In such cases, of course, probe techniques attempting to identify the individuals SA may actually give a misleading impression.  As the situation becomes more complex, and as the operator becomes more skilled, he or she may not be able to identify many specific elements in the environment.  The professional football quarterback, the karate expert, and the fighter pilot all can respond to a complex set of stimuli (on which they have been well trained) with incredible speed.  When asked why they chose one course of action over another, they may be unable to identify all of the elements (stimulus discriminants) in the environment which triggered the response pattern, or they may respond with a "text book" answer having nothing to do with what they actually did.

This phenomenon of skilled performance has been discussed and debated at many levels. With respect to SA, several authors have discussed the role of "mental models", defined as "symbolic representations of conceptual knowledge that exist in long-term memory at varying levels of abstraction" (Cannon-Bowers, Salas, and Converse, 1990).  Harwood *et al* (1988) postulated that the pilot who exhibits good SA must have an accurate mental model, and be able to update the model as the situation changes.  Endsley's (1990) definition of SA suggests that it consists of the person's mental model of the surrounding world, as well as the position occupied by that person in that world.  She also discusses schemas as being critical to SA.  Schemas are defined as "memory stores which organize knowledge into integrated meaningful frameworks" (Shrestha *et al*, 1994).  Fracker (1988) explicitly recognized that schemas are critical to gaining an understanding of the situation and triggering response patterns.  If the incoming sensory information matches a schema in long-term memory, the pilot does not have to attend to every aspect of the environment to have good SA.  In other words, the existence of appropriate schemas (and the ability for them to be activated by the appropriate match with incoming stimulus streams) constitutes, in itself, a level of SA.

### Approaches to Measuring Schema Acquisition and Demonstration

In the present case, the term "schemas" will be used to refer to a class of responses that

are over-learned, and are based on a frequent one-to-one mapping between certain stimulus elements and certain response requirements. More generally, schemas refer to the individual's characteristic way of responding to a specific, complex set of environmental demands. For example, an individual pilot who sees a specific formation of enemy aircraft may "instinctively" carry out a specific type of evasive or attack maneuver. This "instinctive" reaction, we believe is really the selection of one of several potential schemas that have been built up over training in the person.

The complement of schemas that are available in response to this environmental set of stimuli may have fairly obvious stimulus "triggers", or the triggers may be extremely subtle. The fact that there are four planes approaching rather then two, the fact that they are spread a certain distance apart, the fact that they are of a certain type, are all obvious determinants of schema selection. The actual schemas selected, however, may be based on extremely subtle and maybe even idiosyncratic stimulus characteristics for that person. Subtle, barely perceptible movements of one of the aircraft may determine that an evasive maneuver rather than a particular attack maneuver will be selected, or may even determine the selection of one of several available attack maneuver schemas. The premise here is that if the individual possesses his or her "normal" SA, the response selected to this complex stimulus presentation will be consistent with that which was trained and typically used.

Under this approach, the probing of the individual's ability to select and implement an appropriate schema for a given environmental condition would seem to be an excellent assessment of the person's SA. In those complex situations requiring the implementation of schemas, an ultimate awareness and sensitivity of the person to the environment is demanded. This appears to be clearly distinct from most of the kinds of SA measured by the SA measures proposed above. As such, therefore, it would appear that data obtained from a probe of the person's implementation of schemas would be non-overlapping with, or at least complementary to, SA assessments gathered in other ways. For this reason, we have chosen to incorporate several experimental measures of schema acquisition and implementation into SAFTE.

### SAFTE's Techniques for Measuring Schema Acquisition and Demonstration

As an initial implementation, relatively simple (and easy to analyze) situations involving the development of schemas were introduced into the SAFTE system. A set of four tactical situations was developed involving air-to-air engagements with various configurations of enemy aircraft. These scenarios essentially involve minimal differences in the initial conditions (e.g., enemy aircraft position and maneuvers) which, nevertheless, indicate that the pilot should take radically different actions. For instance, a small movement of one or two approaching aircraft indicates the presence of fighters about to attack rather than bombers. Depending on the subject's awareness of these small discriminants, the appropriate action might be either to attack, or to turn and escape. In practice, subjects would be exposed to these differences many times in training, presumably up to the point where appropriate schemas would have developed. In the test mode, the pilot would be exposed to the scenario containing the relevant cue and asked to respond to it as quickly as possible. The time to identify the specific tactical situation will be the primary dependent measure. Exploration of this approach may reveal that the operator's actual response may be a better measure of SA than his or her verbal report. In this case, the measure of SA could be the actual piloting response to the tactical situation (e.g., change of course, weapons enable, etc.).

In this approach, therefore, either verbal or performance measures of SA could be

obtained. In the case of a verbal response, the response would simply be categorized as either correct or incorrect -- meaning that either the appropriate response (schema) was or was not activated. In the performance response mode, classification can be made not only on whether the appropriate maneuver was made, but also on specific measurement factors such as time-to-initiate the maneuver (RT), and other performance-based measures of merit (Venturino, *et al*, 1989).

**SECTION FOUR**

**DEVELOPMENT OF THE SAFTE FLIGHT SIMULATION CAPABILITY**

SAFTE Theory of Operation

This section provides an overall description of the configuration of hardware and software in the SAFTE system, as well as providing an operational description of each of the major portions of the program. Detailed technical descriptions of the hardware and software requirements for both the simulation and graphics machines are provided in Appendices 1 through 4. If the SAFTE system is being hosted on hardware other than the systems provided, the following sections on requirements will need to be reviewed to assure proper system configuration.

Overview

The SAFTE system runs on two Pentium class machines. One machine serves as the simulation machine and the other handles graphics tasks. The simulation machine executes the F-16 model and other simulation models, receives input from the user, logs data and controls the execution of each scenario. The graphics machine receives data for its displays from the simulation machine over the parallel port and displays the HUD, instruments and the out-the-window (OTW) view. The graphics machine should be the fastest machine available to allow the highest level of graphics performance. The majority of simulation activities occur on the simulation machine.

Hardware System Requirements

Simulation System Hardware:
1. 100MHz Pentium PC or better
2. VGA video board and compatible monitor
3. 16 Mb RAM and 500 MB hard disk space (or more depending on data collection requirements)
4. Parallel port with bi-directional capability (via CMOS setup)
5. ThrustMaster Pentium compatible game board with trim pot
6. ThrustMaster controls:
      A. FLCS flight stick
      B. TQS throttle
      C. RCS rudder

Graphics System Hardware:
1. 120MHz Pentium PC or better
2. Video board supporting VESA 640x480x256 resolution and color (Number 9 card recommended)
3. 16 Mb RAM and 500 MB hard disk space
4. Parallel port with bi-directional capability (via CMOS setup)

System Interconnect:
      Shielded Centronix style parallel port cable supplied by NTI

Simulation System Hardware

The simulation hardware consists of a Pentium class PC running at 100MHz or better, a ThrustMaster Pentium-grade game card, and one set of ThrustMaster controls as specified in the hardware requirements section.

ThrustMaster Controls

The ThrustMaster controls are a combination of digital and analog inputs, which are read by the interface software. The analog inputs (which include the roll, pitch, rudder, and throttle) are generated by creating a low to high transition on a control channel of the control interface of the game card. A high pulse immediately appears at the corresponding input channel of the game card whose length is proportional to the position of the control being sampled. The trim pot adjusts the range of values of the analog channels.

The digital inputs are divided into two classes: binary inputs and character inputs. The binary inputs are generated by user defined buttons on the flight stick and are either on or off (1/0). The character inputs are generated by the rest of the buttons on both the flight stick and the throttle and appear as user defined ASCII characters coming from the keyboard. Refer to the ThrustMaster FLCS and TQS documentation for further information about the controls and their programming.

Pentium PC

The PC on which the SAFTE program is designed to run is a generic Pentium class machine with the addition of a ThrustMaster game card. To provide real time scheduling of events within the simulation the real time executive of the software utilizes the hardware of the PC system timer to create a precisely timed clock pulse that is used to sequence the real time tasks. Because the system timer is used by DOS to manage the time-of-day clock, and this function is taken over by the SAFTE program. SAFTE does the management of the time-of-day clock while it is running.

The operation of the system timer is as follows: a value from 0 to 65535 is latched into the timer's register and the circuitry automatically begins to decrement this value to zero every 0.84 microseconds. On reaching zero a clock pulse is generated, the old value is automatically reloaded into the counter and the decrementing process resumes. For DOS the value loaded causes a clock pulse to be generated at a rate of 18.2 Hz. The SAFTE simulation program loads a user-specified value that generates a clock pulse at a rate suitable for executing the F-16 model. Currently this rate is specified to be 50 Hz.

Graphics System Hardware

The hardware of the graphics system is also a generic Pentium class machine similar to that of the simulation system with the following differences: First, the processor is faster, 120 MHz or better, to provide for the smoothest possible graphics performance. Second, the video board used is of maximum performance, again to enhance the graphics display. Third, there are no controls hooked into the graphics system and thus no game card is needed.

The essential function of the graphics system is to receive information from the simulation system and to display corresponding graphical output in as close to real time as possible. To provide as high a throughput as possible all other functions are carried out by the simulation system.

System Interconnection

To get information from the simulation computer to the graphics computer the PC's parallel port was chosen, as it is a built-in resource of adequate speed. The current implementation of the parallel port software requires that the parallel port be capable of bi-directional transfer and that a custom cable (supplied with the SAFTE system) be used. The current effective transfer rate of the interface in on the order of 10K bytes per second.

Software

The purpose of the SAFTE system is to provide a flexible tool for testing embedded performance and SA measures in a real life task (in this case piloting an aircraft) while running on as close to a standard PC platform as possible. To accomplish this goal the software system incorporates the following features:

1. A realistic aerodynamic model of the F16 aircraft having takeoff and landing capabilities, speed brakes and landing gears. The model is executed in a real time mode in order to provide a realistic response to the pilot's inputs.

2. Programmable SA probes, unusual attitudes and screen blanking plus open ended scenario control capabilities

3. Simulation objects such as other aircraft, radar threats, etc.

4. A generic F16 HUD with a radar warning receiver (RWR), air-to-air radar system, etc.

5. Weapons system and countermeasures

6. Continuous logging of aircraft position, control inputs, and all pertinent events

The subsystems of the main software tasks (the simulation and graphics programs) are shown schematically in Figure 1. The software subsystems are divided into background and real time tasks. Data generated by the simulation side, consisting of the aircraft's state vector and navigation information, is transmitted over the parallel port to the graphics side, and updates the out-the-window (OTW) display as well as the HUD. Additional less frequent information is transmitted over the port in the form of messages directed to various systems on the graphics side including the RWR and air-to-air displays.

The software system requirements are as follows:
      Simulation System Software:
            1. MSDOS 6.2 or later
            2. ThrustMaster Supplied Software
            3. DOS4GW.EXE (Tenbury via Watcom)
            4. CAL.EXE
            5. SIM.EXE
            6. SAFTE.B50 Data File
            7. SAFTE Data Files (See Listing 1 of the appendix)
            8. Files A.BAT, M.BAT, and S.BAT

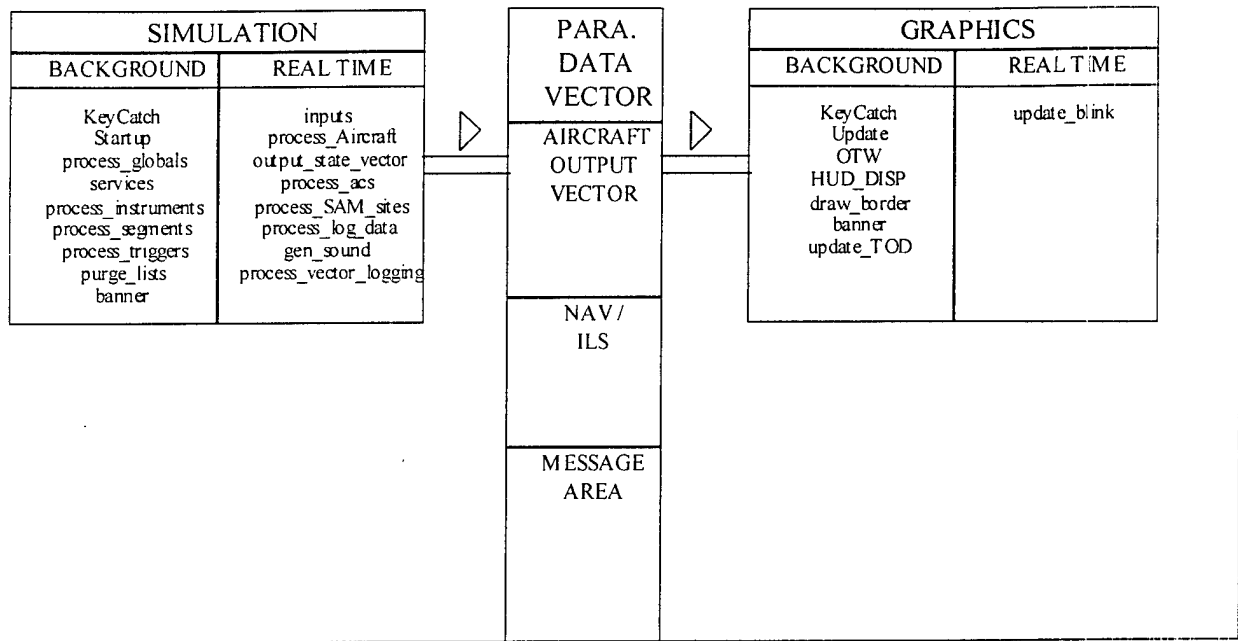| SIMULATION | | PARA. DATA VECTOR | GRAPHICS | |
|---|---|---|---|---|
| BACKGROUND | REAL TIME | | BACKGROUND | REAL TIME |
| KeyCatch Startup process_globals services process_instruments process_segments process_triggers purge_lists banner | inputs process_Aircraft output_state_vector process_acs process_SAM_sites process_log_data gen_sound process_vector_logging | AIRCRAFT OUTPUT VECTOR | KeyCatch Update OTW HUD_DISP draw_border banner update_TOD | update_blink |
| | | NAV / ILS | | |
| | | MESSAGE AREA | | |

Figure 1. Subsystems of the software tasks

Graphics System Software:
1. MSDOS 6.2 or later
2. DOS4GW.EXE (Tenbury via Watcom)
3. GRAPHICS.EXE
4. Graphics Data Files (See Listing 2, of the appendix)
5. Files G.BAT and V.BAT

Simulation System Software

The main functions of the simulation software are

1. to run the aircraft model and other simulation models
2. control SA measures and other events
3. receive inputs, log data, and output information to the graphics system

All these activities plus several others are executed within the context of the real time executive. The executive (subsequently referred to as the RTK) consists of two main endlessly cycling loops, the background loop and the real time loop. Within the background loop are all the tasks that do not require precise timing for their execution. The real time tasks consist of tasks that are time critical. The F-16 model and other aircraft models as well as models of threats, bombs, missiles, etc. fall into this category, as they require their execution to conform to the passage of actual or "real" time to give a sense of realistic behavior.

The reader interested in more specific technical details of the SAFTE system is referred to the extensive descriptions of the SAFTE system provided in Appendix 1 (Description of the SAFTE System Software), Appendix 2 (SAFTE System Configuration), Appendix 3 (SAFTE System Editing Tools), and Appendix 4 (Instructions For the SAFTE Simulator Controls). For the reader interested

in using the SAFTE system after it has been set up, a "User's Manual" has been developed, and is included in this report as Appendix 5. This is intended to guide the researcher in the actual use of the system, including the kinds of data output to be expected.

# SECTION FIVE

## INITIAL SYSTEM TEST AND DEMONSTRATION PROJECT

### INTRODUCTION

The SAFTE system represents an innovative development in at least three major areas: 1) It involves a significant enhancement of the aerodynamic fidelity achievable with a PC-based system, 2) it incorporates new techniques for assessing situation awareness, along with older techniques, and 3) it provides embedded situation awareness measures in the context of real-world flight challenges. To achieve this product, an enormous amount of new software had to be created, along with significant developments in the creation of realistic flight scenarios and implementation of actual situation awareness measures. The final deliverable product therefore represents a completely new system. As such, the system must be subjected to extensive alpha/beta testing of the hardware and software, as well as the extensive validation and psychometric testing of the SA metrics. Obviously, in any ultimate sense, such efforts in themselves will take several years and involve the independent assessment by a large number of laboratories. However, it was desirable and necessary to carry out initial testing prior to final delivery in order to maximize the possibility that the delivered product will constitute the most efficient and useable implementation of the basic concepts. This section describes the first system test and demonstration on SAFTE.

The present demonstration effort had two major goals: 1) it was designed to provide a rigorous test of the software and hardware in the initial SAFTE design, and 2) it was designed to provide initial and fundamental data on the basic feasibility and psychometric characteristics of the SA measures, as well as the flight performance measures. With respect to the first goal, the intent was to provide a "pre-beta" test of the initial software design. Although initial alpha testing had been carried out during software development, the system had never been required to perform independently and interactively. It was inevitable that when such demands were made on the software, "bugs" would be uncovered, and modifications would be required. In the interest of efficiency and economy, it was decided that these activities would be carried out in conjunction with the testing of actual subjects. Thus, the two goals were integrated into one effort. In effect, although it was recognized that the data from the early portions of the study could be contaminated by required software changes, it was considered useful to gather such data in the hope that at least some of it would be informative. In any case, it was also believed that the data from the later portion of the study would still be valid, and that both goals would have been accomplished in the context of a single study.

### METHODS AND PROCEDURES

The basic design of this demonstration involved having civilian pilots with varying degrees of flight experience "train" on the SAFTE Flight Simulator. Such training involved ten hours of practice in a scripted set of flight tasks (see Appendix 6 for a description of these flight tasks). Although performance metrics were gathered and inspected during this period of time, it was also recognized that software changes would be required during the training. Therefore, the metrics could be influenced by such software changes.

At the end of the ten hours of "training", subjects began the "testing" phase. This consisted of a series of 20 "missions" which were to be flown by each subject (see Appendix 7 for a complete description of these tasks.) The missions involved combinations of tasks that had been practiced

32

during the training phase. During the missions, multiple examples of each type of situation awareness measure were presented, and these are also detailed in Appendix 7. Flight performance and SA measures were obtained and analyzed for this ten hours of performance.

The only independent variable in this demonstration study was the amount of flight experience of the subject. Two levels of experience were defined -- 0 to 200 hours, and over 200 hours. Only total flight hours were considered in this categorization, and no distinction was made between type of aircraft or training, since virtually all hours would have been in civilian aircraft.

Subjects.

Subjects were recruited through local advertising at the Center for Aerospace Sciences of the University of North Dakota. Initially, 104 subjects began the training sessions. Subjects were paid by the University at a flat rate of $100.00 for completion of the project. All subjects were licensed civilian pilots.

In view of the University setting and the rigorous flight training schedule for the subjects, some attrition of the original subject pool was anticipated. This was especially true since an attempt was made to keep all of the subjects on approximately the same training point at any given period of time. Thus, if the subjects fell too far behind in their SAFTE training, they would have to be eliminated from the study. During the early portion of the study, a slightly higher attrition rate was experienced than had been expected. However, this was still well within the boundaries of original projections. However, midway through the study, North Dakota experienced a period of extremely severe weather, with double-digit negative temperatures for 21 days straight, and a series of five blizzards (eventually causing the University to close and the entire semester to be canceled). This caused additional delays in both the training and testing phases of the effort, to the point that the Christmas holidays and mid-year graduation occurred before the study was completed. The final result was that very few subjects finished the entire 20 hours of the planned study. However, enough completed sufficient testing sessions to permit preliminary statistical analyses.

Scenario Construction.

For both training and test purposes, "canned" scenarios were constructed. These were developed in consultation with the pilot consultant who assured that they represented realistic missions and flight parameters. The scenarios described in Appendices 6 and 7 were developed in this way. A total of 67 training scenarios (with some scenarios repeated in the training sequence) and 10 test scenarios (each repeated twice) were developed. NTI programmers hard-coded these scenario requirements (e.g., the initiation point of the training scenarios and the required evasive maneuvers of enemy aircraft) in separate units for presentation to the subject. To facilitate this process, a "scenario generator" was created by NTI (included in the SAFTE system product). The scenario generator not only facilitated the creation of the "hard-wired" training and test missions required by the present effort, but will permit researchers to generate their own mission profiles to address their research needs.

For the training scenarios, the sequence of "mission segments" presented to the students began with training on a simple take off maneuver, and culminated in training on an air to ground attack. For each segment, the student received a briefing card detailing the requirements for that segment. In addition to this card, the student was given verbal instructions on the general nature of the simulation, the meaning of each HUD instrument, and the operation of all controls. This

was done either by the pilot consultant, by the on-site experimenter, or through a video instruction. In this latter case, instructions about how the flight scenarios should be flown were given through a series of videos prepared by the pilot consultant. In these situations, upon reporting for the session the student would view the five-to-ten minute video pertaining to that day's mission. Each video demonstrated the maneuver required for that session and provided hints concerning the way the maneuver should be carried out.

For the testing sessions, a similar procedure was followed, except that, since the subject would already have been familiar with each of the mission segment requirements, the mission assignment was given in a more formal "briefing" manner. Again, briefing cards were distributed to the subject, who was given an unlimited amount of time to read and study them. The subject retained these cards during the testing session as a kind of "knee-pad" reminder. Again, the actual missions required of the subject, in the sequence required, are presented in Appendix 7, which describes in detail the required mission parameters and tactics.

Scenarios were presented in the same order for all subjects. The first ten testing missions were all different in either environmental condition, assigned activity, threat, or required response. The last ten missions repeated the first ten in a different order than they had been presented initially. Each scenario was designed to last between 15 and 25 minutes, and subjects typically completed two scenarios per session. Scenarios were self-administering. Subjects were instructed to attempt a scenario only once (i.e., if a crash occurred or for some other reason they failed to complete the scenario, they were not to repeat it). However, not all subjects followed these directions, and some repeated scenarios two or more times before proceeding to the next scenario. Thus, the training data analysis presented below does not strictly reflect the same amount of experience for each subject. Rather, it reflects the point at which the subject felt comfortable at having achieved a level of performance for that particular training scenario.

Situation Awareness Measures.

The basic concept of the SAFTE system is to embed situation awareness measures into the flight scenarios. A total of six different types of SA measures were proposed, ranging from basic information about what was in the surrounding environment to an attempt at measuring the development of schemas. For the present demonstration, instances of each of these types of measures were developed by NTI. These were then programmed into selected points in the scenarios. The categories of SA measures and representative examples of each have previously been presented in Section Three of this report.

**RESULTS**

Data Reduction and Analysis.

Flight Performance Measures: The first task in analyzing the results of this experiment was to reduce the vast quantity of flight performance data collected to a manageable proportion, and to select the dependent measures for the flight task analysis. To achieve this, a "data generator" was created as part of the SAFTE system development (Appendix 8). This data generator summarizes the continuously collected flight performance parameters into a series of defined events (altitude change, heading change, weapons release, etc.), and provides a time stamp and aircraft state description for each event. Specific variables presumed to measure the quality of flight performance for different maneuvers were selected. A sample data output for a single subject performing a single mission is also shown in Appendix 8 for illustration purposes. Once

these maneuvers had been isolated, along with the metrics associated with each maneuver, actual data analysis could begin.

Situation Awareness Measures Data Analysis. A major focus of the SAFTE system is the embedded SA measure technique. As noted above, there were six different types of SA measures taken with different numbers of determinations for each measure. Interest primarily was in group differences as a function of flight experience. However, there was also considerable interest in changes in SA performance over the course of the ten hours of testing.

SA data were reduced in different ways depending on the nature of the SA probe. Measures using the "blanking" technique could all be answered by a "yes" or "no" response. It was therefore possible to determine a simple "percent correct" measure. However, a more sophisticated analysis was also possible due to the fact that this approach resulted in four categories of response: "hits" were correct "yes" answers, "false alarms" were "yes" answers when the correct answer was no, "true rejections" were correct "no" answers, and "misses" were "no" answers when the correct answer was yes. This permitted analyses to be carried out using information theoretic metrics, as described by Kantowitz & Sorkin (1983) and Amburn (1994).

Measures of 'recovery from unusual attitudes' involved determining the amount of time between the start of the recovery and the point at which the aircraft wings were straight and level for over three seconds. Measures of 'minimum information flying' required individual analysis of each segment of the flight. As noted later, it became obvious early in the test that the 'schema' measure was not working, and therefore no analyses were carried out on this measure.

Flight Performance Results.

There were two major types of analysis of interest of the present data. One involved the learning curves of various measures for the levels of flight experience, and the other involved differences in absolute levels of performance. Both of these questions were addressed by entering average data into two-way ANOVAs.

For this initial demonstration, six representative variables were selected for detailed analysis, and several others were selected for less detailed analyses. These basic six variables included the following:

1: altitude at the start of a left turn
2: speed at selection of mil-power
3: average heading deviation during straight and level flight
4: average altitude deviation during straight and level flight
5: number of straight and level segments completed
6: number of straight and level readings

The results of the analyses of variance on these factors are shown in Table 1, and the averaged data used in these analyses are given in Appendix 9. These results are discussed more fully in the graphic presentation of results presented below.

## TABLE 1

## RESULTS OF ANOVA ON SELECTED FLIGHT MEASURES

North Dakota SAFTE Demonstration Analysis

FM01 - Altitude at Start of Left Turn
FM02 - Speed at Selection of Mil-Power
FM03 - Average Heading Deviation during Straight & Level
Flight
FM04 - Average Altitude Deviation during Straight & Level
Flight
FM-A - Number of Straight & Level Segments
FM-B - Number of Straight & Level Readings

|  | Effect | df Effect | MS Effect | df Error | MS Error | F | p-level |
|---|---|---|---|---|---|---|---|
| FM01 | 1 | 1 | 3508886 | 21 | 1406654 | 2.494491 | 0.129191 |
|  | *2 | 15 | 955791 | 315 | 560138 | 1.706349 | 0.048476 |
|  | 1x2 | 15 | 334125 | 315 | 560138 | 0.596506 | 0.877324 |
| FM02 | **1 | 1 | 191166.5 | 21 | 20198.2 | 9.464529 | 0.005725 |
|  | *2 | 12 | 17426.6 | 252 | 9077.04 | 1.919851 | 0.032505 |
|  | 1x2 | 12 | 7130.3 | 252 | 9077.04 | 0.785535 | 0.665255 |
| FM03 | 1 | 1 | 0.23029 | 30 | 2.135372 | 0.107845 | 0.744892 |
|  | 2 | 16 | 0.887556 | 480 | 1.519589 | 0.584076 | 0.896499 |
|  | 1x2 | 16 | 1.82256 | 480 | 1.519589 | 1.199377 | 0.264074 |
| FM04 | 1 | 1 | 17.7105 | 30 | 121.204 | 0.146122 | 0.704964 |
|  | 2 | 16 | 83.8089 | 480 | 109.3112 | 0.7667 | 0.723872 |
|  | 1x2 | 16 | 111.7826 | 480 | 109.3112 | 1.022609 | 0.430701 |
| FM-A | 1 | 1 | 368.9639 | 30 | 265.5591 | 1.389385 | 0.247774 |
|  | 2 | 16 | 55.5246 | 480 | 75.6553 | 0.733916 | 0.75968 |
|  | 1x2 | 16 | 82.209 | 480 | 75.6553 | 1.086625 | 0.364805 |
| FM-B | 1 | 1 | 1316803 | 30 | 345865.2 | 3.807274 | 0.060424 |
|  | 2 | 16 | 46028 | 480 | 59155.1 | 0.778091 | 0.711109 |
|  | 1x2 | 16 | 66392 | 480 | 59155.1 | 1.122332 | 0.330669 |

1 = Experience Level (< 250 Hrs, >=250 Hrs)
2 = Attempt Number
* p > .0500
** p > .0100

Considering first the deviation from assigned altitude at the initiation of a left turn, Figure 2 indicates that both low and high experienced subjects initially missed the assigned altitude by 300 to 600 feet. Both groups show a significant learning curve over the first 10 tries. However, the low experience group continues to initiate left turn earlier than instructed, and ultimately is

under-estimating the turn by almost 200 feet. The high experience group, on the other hand, generally levels off at close to the assigned altitude. Statistically, the learning curve is significant at <.05, although the absolute differences between low and high experience groups never reached statistical significance.

## DEVIATION FROM ASSIGNED ALTITUDE FOR INITIATING LEFT TURN
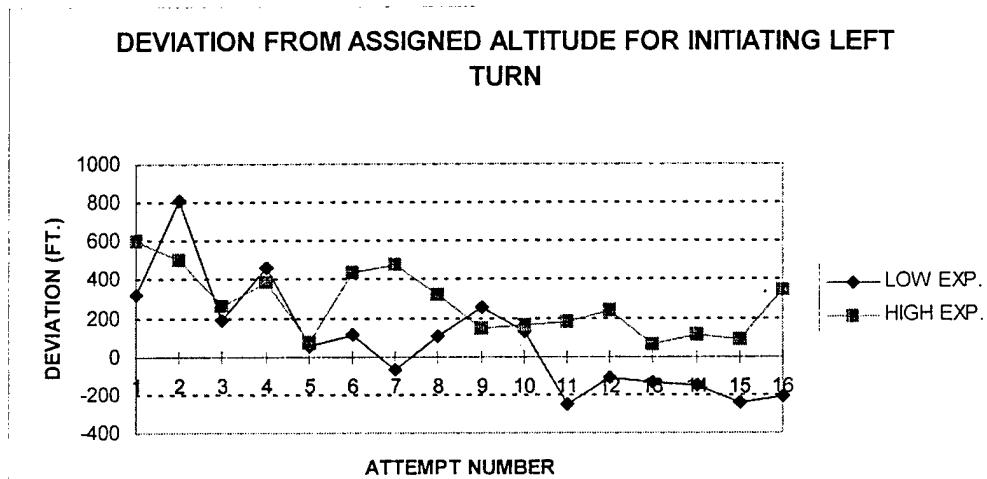


Figure 2. Deviation from assigned altitude for low and higher experienced subjects.

On other hand, Figure 3 on the next page illustrates that deviations from the assigned speed at selection of mil-power show significant differences between low and high experienced individuals. In this case, however, the low experienced subjects tend to be more accurate in their performance than the high experienced subjects. This effect is significant at <01. In addition, there is a significant effect of attempt number at p<.04, although this appears to be very variable.

None of the other flight measures selected for analysis show statistically significant differences either as a function of practice, or between low and high experienced subjects. One variable, however, shows a clear-cut performance improvement with practice. This is shown in Figure 4 on the next page. During the extremely difficult ground attack maneuver, the deviation from assigned altitude for the roll-out showed significant improvement over 10 practice sessions. Although this failed to reach statistical significance, it illustrates the type of changes that can be expected in the SAFTE flight performance measures.

Situation awareness measures

"Blanking" technique SA questions. Analyses of the SA questions presented while the simulation was suspended were carried out based on the type of question involved. Type "A" questions essentially requested information about surrounding environmental conditions. Type "B" questions required some projection to future events. Type "C" questions involved more complex calculations of future patterns more derivative information processing. Again, these were analyzed either in terms of the percent correct, or in terms of an information-theoretically metric (d').

37

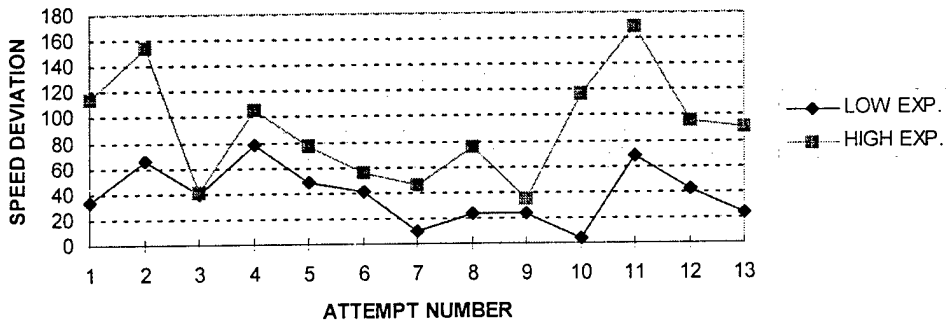## DEVIATION FROM ASSIGNED SPEED AT SELECTION OF MIL-POWER



Figure 3. Deviation from assigned speed at selection of mil-power.

## DEVIATION FROM ASSIGNED ALTITUDE FOR ROLLOUT ON GROUND ATTACK MISSION
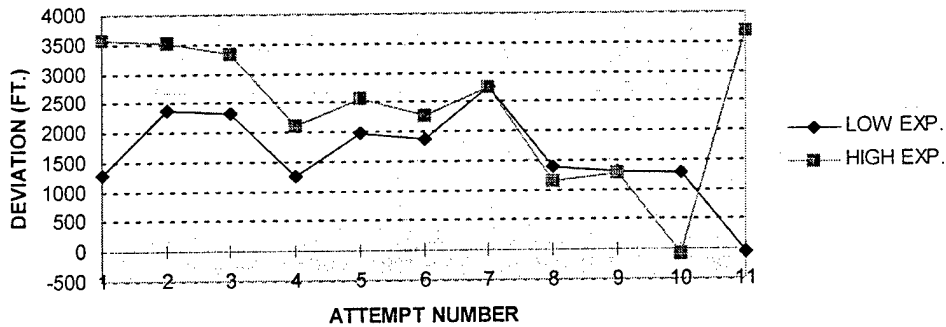


Figure 4. Deviation from assigned altitude during the roll-out (ground attack).

With respect to the percent correct metric, there was little difference between the low and high experienced groups, and little difference between the types of SA measures taken. During the CAP missions, somewhat more deviation is seen in the type "C" measure between the low and high experience groups. Again, however, the low experienced group appears to perform somewhat better than the high experience group.

On the other hand, the information theoretic measure appears to be more sensitive to the differences between the groups. Figure 5 illustrates d' for all ground attack missions by experience level. Whereas the percent correct metric showed little difference between groups across training, the d' measure shows interesting differences. The experienced subjects show a large difference in d' on question type "C", indicating better processing than the high experienced subjects.

**d' Measure of SA Over All Mission Types**

Figure 5. d' measure for "blanking" type questions during ground attack missions.

A similar results was seen in the analysis of all mission types with the information theoretic measure. Again, low experienced subjects performed better on the more complicated type "C" question than high experienced subjects.
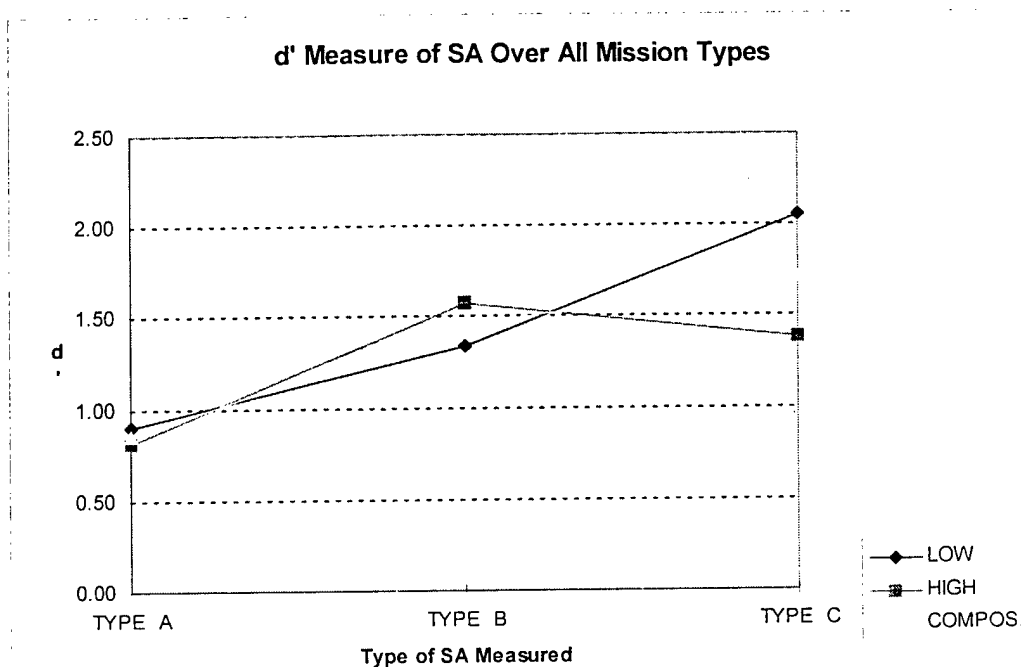
"Minimum information flying" SA technique. It will be recalled from Section Three that the subjects were instructed during certain portions of the mission to turn the displays off as much as possible consistent with safety and mission accomplishment. For the most part, these portions were introduced during straight and level flight, where the requirements were primarily to maintain altitude and speed, with some navigation. Some portions were introduced during turns or altitude changes.

In view of the fact that most subjects never achieved a high level of skill in flying the F-16, data obtained from this measure during the demonstration are of extremely limited value. It would be relatively meaningless to quantify the choices of the subjects, since they were performing well below the level of trained military pilots. For this reason, this measure was not analyzed in the present data.

Recovery from unusual attitudes (UA's) technique. As noted previously, the use of unusual attitudes (UA) to infer SA is an indirect approach. At best, the inference is that if the pilot efficiently recovers from UA's, he or she can rapidly assess a spatal situation, develop rapid spatial SA, and respond efficiently. In SAFTE, the UA's are presented at a discrete point in time (after a "blanking" question), so it is possible to determine rather precisely how long it took to recover. This is the basic measure obtained.

In the present demonstration, the civil aviation pilots proved relatively incapable of recovery from the unusual attitudes presented. This was true even though they had been thoroughly briefed on recovery procedures, and although some of the instructor pilots regularly flew unusual

attitude recovery practice. The speed and responsiveness of the F-16 aircraft appeared to overwhelm them, to the point that few were able to recover in any time frame that would provide meaningful data. For this reason, the measure was not analyzed beyond a superficial inspection.

"Schema" measures of SA. This experimental technique was not successful in the demonstration. It became clear during the training that even with the extensive practice provided in the air-to-air scenarios, subject never reached the level of automaticity that would be necessary for the measure to work. Therefore, no analyses were carried out on this measure.

Many other analyses were carried out on the data generated in this demonstration. Most of these proved non-significant statistically, and contributed little to the original parametric goals of the effort. For completeness, however, figures showing results of some of these non-significant analyses are presented in Appendix 10.

DISCUSSION

Procedural considerations in the SAFTE system. Obviously, the sample of results presented above cannot be considered definitive in any sense. They are intended simply to indicate the kind of results that can be generated by the SAFTE system. As such, they are illustrative of the types of analyses that might be carried out by an investigator.

The principal outcome of this demonstration project was the development of a set of recommended procedures for utilization of the safety system. During this project, the majority of procedures initially implemented proved feasible and workable. However, there were a considerable number of lessons learned which, even at this early stage, modify recommendations for future implementations. These positive and negative lessons are discussed below.

One of the first things that became obvious during this demonstration study was that civilian pilots, even those with some degree of experience, such as instructor pilots, were not able to acquire the skills necessary to fly the F-16 simulation over a 10 hour instruction period. It had been hoped that the incremental instructions given would allow at least the experienced pilots to perform at a plateau level by the end of training. This proved not to be the case. Although some of the subjects did achieve an apparent plateau during the ten hours of testing, these were too few upon which to base any conclusions. A first principle, then, is that in any utilization of the safety system with non-military, non-fighter-experienced pilots, a considerable amount of training will be required.

On the other hand, it should also be noted that the sequence of training materials used in the present demonstration proved to be effective in yielding a learning curve, even for the inexperienced civil aviation pilots. While plateaus were not reached frequently, the subjects did report being comfortable with the progression from basic takeoff to complex air to ground maneuvers. It would be expected, therefore, that pilots having some jet aircraft experience would be very comfortable with the types of training utilized in this demonstration. It is recommended that if the subjects are experienced military pilots, the training sequence used here and presented in Appendix 6 will be completely satisfactory. In fact, depending on the experience level of the pilot, this training could probably be significantly reduced.

With respect to the actual procedures used in running this project, there were some surprising results. The safety software system had been designed with the intention that the entire procedure would be self-administering. Subjects were given extensive instructions about how to

initiate sequences, data logging, and other procedural details. The complexity of these instructions was kept to an absolute minimum. Yet, while many subjects followed the instructions, a significant number either found them impossible to follow, or decided to ignore them. The most common error was for subjects to repeat missions on which they felt they did poorly. This clearly violated their instructions. Other problems included entering wrong identification numbers, and failing to log data properly. It therefore appears that the procedures implemented in the safety system to permit self-administration were not successful, at least for this subject group. Therefore, for the moment, it must be recommended that the experimenter plan on monitoring all aspects of the study closely.

Considerations in scoring the flight measures. In itself, the system for data logging incorporated into the safety system appeared to work very well. The system collects an extremely large amount of data on each flight and mission. In other applications, this is proven to be a formidable obstacle to analysis in many simulation systems. The existence of the data generator discussed in Appendix 8 significantly alleviated this problem in the SAFTE demonstration. The data were summarized in an extremely usable fashion, without sacrificing significant detail. This is not to say that data reduction in the safety system is a turn-key affair. The data generator does not constrain the experimenter to a "canned" approach to data analysis. Instead, it simply presents the summary data in a form that can be manipulated by the experimenter to carry out any statistical analysis desired. Therefore, it is still necessary for the experimenter to determine what aspects of the flight maneuvers to analyze, create definitions of these aspects in operational terms, decide on which of the SA measures should be analyzed and in what form, and finally to implement these analysis approaches in software.

In carrying out the above analyses, the experimenter will be significantly aided by the decisions that have already been made concerning definitions of specific maneuvers, as described in Appendix 8. In practice, this turned out to be one of the more challenging efforts of the data analysis process, and the existence of the data generator now simplifies this problem for the experimenter. Determining, for instance, when a turn actually occurred required defining in a quantitative way the differences between a real turn and a slight deviation of the airplane in a lateral direction. This was done in present case in consultation with pilot consultants, and appeared to produce appropriate classifications in this demonstration project. The experimenter is therefore free to use these as they currently exist. However, is still possible for the experimenter to modify these analyses carried out by the data generator through relatively simple modifications of the code.

The flight measures themselves, even in this limited demonstration with civilian pilots, appeared to operate efficiently. Learning curves were obtained, with some differences appearing as a function of training and experience. An intriguing result was that lower experienced pilots tended to stay closer to briefed parameters than more experienced ones. This may be due to their status as novice students, more accustomed to following directions, or to some other factor. The important thing for the present demonstration is that statistically significant differences were found with the SAFTE system.

SA measures analyses. The data output of the first three situation awareness measures -- the probe techniques -- is extremely straightforward. The percent correct answers for each question are summarized by the data analysis program, and can be grouped in any desired way by the experimenter. Similarly, from the data output it is a relatively trivial task to formulate the two by two tables necessary to calculate d'. In the present demonstration, the procedures recommended by Kantowitz & Sorkin (1983) were used, although other computational formulas are available.

41

Scoring recovery from unusual attitudes can be somewhat complex. It is necessary to establish an objective criterion for when the individual has recovered from the unusual attitude. In the present case, the definition selected was when the aircraft achieved straight and level flight for a given period of time, and the primary metric was the time from the initiation of the unusual attitude to this recovery point. Again, this analysis becomes relatively easy by utilizing the data generator and simply scoring the amount of time between the two events. Other scoring criteria might also be utilized, including time to initiate the first correct recovery action, the number of inappropriate recovery actions, and analysis of altitudes achieved during various phases of the recovery compared to ideal values.

Clearly, the most difficult situation awareness measure to analyze is one included under the heading of "minimum information flying" -- measure No. 5. In the present demonstration, no extensive analysis of this measure was carried out in view of the limited to value of the data obtained from commercial pilot's. However, general concepts for how such evaluations might be done range from relatively simple approaches -- e.g., determining when the absence of information causes a significant accident or safety condition -- to more sophisticated analyses dealing with the subject's mental model. This latter approach involves some degree of speculation on the part of the experimenter or analyst, since there must be some attempt to infer why the subject felt that no new information was necessary. However, this can frequently involve a relatively straightforward set of assumptions.

## SECTION SIX

## INSTALLATION OF A MODIFIED SAFTE SYSTEM IN A HUMAN CENTRIFUGE

### INTRODUCTION

This report details the work NTI has accomplished in the revised statement of work, Task 6. SBIR Contract No. F41624-95-C-5008. It covers only the work associated with installing the Situation Awareness Flight Training Evaluator (SAFTE) into the Brooks Air Force Base human use centrifuge. SAFTE is a PC-based, F-16 flight simulator with performance and situation awareness measures. A short description of the status of each subtask is provided below. The last subtask was to explore ideas, beyond the currently funded effort, for future uses of the SAFTE simulator in the centrifuge environment. Therefore, the narrative of this subtask describes several desirable enhancements to the simulator that could contribute to the validity of centrifuge research.

### OBJECTIVE

The primary objective of this effort was to adapt the SAFTE flight simulator to the Brooks centrifuge in order to test the feasibility of using it for piloting performance measurement under high G loading.

### RATIONALE

The basic SAFTE system, when installed in the Brooks AFB centrifuge will enable acceleration scientists to measure human piloting performance in high G environments in several planned experiments. Data collected will objectively determine the effectiveness of current and future high G protection equipment and techniques. These data will be correlated with the physiological variables as well.

### SUBTASKS

Sub-task 1    In this subtask, NTI modified the SAFTE software to allow installation into the Brooks human centrifuge. The modifications included:

1. Interfacing analog voltages from the current centrifuge control stick into the SAFTE computer.
2. Converting SAFTE's HUD display of G forces from the aircraft model into analog voltages that control the centrifuge's rotational speed and, hence, the G forces on the pilot or subject.
3. The development of a primitive automatic throttle positioner to maintain the appropriate aircraft speed for flying the various scenarios.

Sub-task 2    NTI reviewed the list of equipment selected by the government to implement the installation of SAFTE and other related work, suggesting changes where needed. NTI acquired all the hardware and software products necessary to accomplish the objective. All hardware was delivered to the appropriate government representatives as soon as possible for implementation in the centrifuge. All systems performed as expected.

Sub-task 3    NTI worked with the government scientists and engineers to provide mission

scenarios with high G requirements for a demonstration of capabilities. Because of the efficiencies of the government/contractor team in implementing the hardware/software SAFTE system into the centrifuge, NTI was able to go beyond the task requirements and implement additional concepts that originally were programmed for future funding.

1. A simple scenario editor tool for designing specific centrifuge/subject flight profiles was created. It creates visual cues the subject uses to make turns, pitch changes, and rolls thus leading to controlled G maneuvers. From the subject's point of view, it consists of a "highway in the sky" out-the-window display. By flying the aircraft through "hoops" the subject completes the G maneuvers required for the specific centrifuge application. Flying performance measurements are taken during all maneuvers. A utility program combines the logged data and the "hoop" location information to generate an ASCII file with RMS error values, the G forces, hoop number, segment number and other information.
2. The subject actuated switch concept was also implemented. The switch is located on the force stick. Its activation is logged in the data file during the subject's execution of the mission. The latter allows the subject to signal acknowledgment of the occurrence of various events as they happen. For example, to indicate that he has knowingly missed a turn or is outside of expected parameters of flight.

Sub-task 4      NTI worked with the government scientists and engineers to test the installed system and allow subject, near closed-loop control of the centrifuge operation within the bounds of safety. Although closed-loop control could have been implemented, the centrifuge engineering staff recommended against implementing it for two reasons. One, the lag of the centrifuge behind the aeromodel was within acceptable limits (approximately 150 msec). Two, an additional margin of safety is available if true closed-loop operation is avoided.

Sub-task 5      During and following a testing session, NTI staff and consultants met with government scientists and engineers to identify and provide concepts for future modifications to SAFTE for anticipated centrifuge research needs. Each of these identified enhancement concepts is described below. Because of the efficiency of the work, three of the "future" concepts were implemented under the current effort. They are the design and implementation of a simple scenario editor to create flight specific profiles, the creation of a "highway in the sky" out-the-window display with utility program to integrate logged data with the flying and centrifuge events, and the addition of a subject actuated switch on the stick that is logged in the data file.

The eight concepts described below were intended to span the range from very practical, normal upgrades to advanced concepts such as training air combat maneuvers and tactics in the centrifuge rather than in an airframe. The Gantt Chart included after Concept 8 is intended to show the dependencies among some of the concepts.

Concept 1 - Auto pilot throttle

The control of SAFTE's simulated F-16 was designed for stick, throttle and rudder inputs. Non-pilot operators find it difficult to fly on a prescribed flight path when they must coordinate all three inputs. Generally, operation of the simulated aircraft requires stick and throttle command inputs at a minimum. NTI's programmer has created a compensatory throttle outside the F-16 aeromodel that attempts to maintain a fixed airspeed throughout missions involving turns, climbs and dives. However, a speed auto pilot that is integrated with the F-16 aeromodel would provide for smoother operation and enhance the quality of the data obtained from the subject.

A throttle input to the model can be created within NTI's aeromodel that would hold each subject's flight through a scenario to the same speed. If subjects are allowed to reduce their speed through a set of turns, climbs or dives, then the task becomes progressively easier and the subject will also be less +Gz stressed.

*WorkPlan*
The development, integration and testing of a speed auto pilot can be completed as follows:
1. Define the magnitude of the problem:
   test runs measuring the performance of several subjects flying the hoops,
   measure the frequency of speed changes to compare with same run after modifications.
2. Create throttle auto pilot (Dr. Stevens, GTRI)
3. Integrate auto pilot with SAFTE.
4. Test modified software.
5. Compare data from old and new software.

Period of work:              4 weeks

## Concept 2 - Design for coriolis experiment

Generally, +Gz is experienced in flight with changes to the aircraft that involve turn radii of thousands of feet. In the centrifuge, +Gz is generated by rotating the gondola containing the subject around a center point only 15 to 20 feet from the subjects head. In an aircraft angular motion is minimal; in the centrifuge it cause adaptation of the balance organ (semi-circular canals) such that head movements or speeding and slowing the centrifuge can cause illusions of coriolis (cross coupling) that may affect operational performance measurement. If one uses the centrifuge to determine that a modification to a pressure suit significantly improves flying performance, how can one be sure that it is not just correcting some centrifuge artifact, like the coriolis effect, rather than something that is a problem in an actual airplane? In other words, the suit modification might have no effect as a counter measure in flying an actual aircraft. In short, differences between centrifuge and aircraft effects on performance need to be understood to properly interpret research findings from the centrifuge.

NTI could assist the government acceleration scientists to design an experiment to assess these effects. To conduct this experiment in its entirety, it would be necessary to compare performance data from the centrifuge with that from an actual flight using pilots. This could be accomplished with the Calspan/SRL F-16 inflight simulator. On the other hand, an incomplete, but useful, experiment can be conducted entirely on the centrifuge. Performance can be compared at rest, at rest with head motion, under +Gz, under +Gz with small head movements and under +Gz with large head movements. The coriolis effect would be indicated by significant differences between the +Gz with head motion conditions and the at rest conditions.

*WorkPlan*
The contractors would:
1. Write the Research Protocol.
2. Validate all performance measures and systems for correct operation.
3. Reduce, analyze and interpret the simulator data.
4. Write report of research findings and present them at the ASMA convention.

Period of work:              12 weeks

## Concept 3 - Implement throttle input in gondola

To give pilots a more realistic flying experience in the centrifuge, a throttle needs to be added to the gondola for operation of the F-16 simulator. With the addition of the throttle, the centrifuge would become an excellent tool for training air engagement tactics that would include the G force consequences of actions taken, Gz and some Gx.

*Workplan*
The government would provide the throttle, mount it in the gondola and provide the appropriate voltages to the A/D converter of the simulator computer. NTI would:
1. Interface the throttle to the software through the existing A/D converter.
2. Make the throttle selectable as an option when pilots are trained or tested.
3. Create special scenarios for the intended use.
4. Modify the system fidelity for pilot acceptance.
5. Validate all performance measures and systems for correct operation.

Period of work:    8 weeks

## Concept 4 - A-LOC

Almost loss of consciousness (A-LOC) is a condition in which a pilot losses vision (tunnel vision or gray out) from high Gz onset that does not result in a loss of consciousness. This condition is followed by the return of vision with the blood flow restored to the brain. A question yet to be answered is "how does this condition affect pilot performance once vision is restored?" With SAFTE now in the Brooks AFB centrifuge, this condition can be researched with objective piloting performance measures. Government acceleration scientists can spin subjects up to A-LOC while they are performing various missions and record performance under various levels of gray out. Performance can then be correlated with the measures of gray out to assess the relationships. Guidance on the limitations of using A-LOC as a combat strategy can then be formulated from the results.

*Workplan*
NTI scientists would work with the government providing recommendations for scenario changes, performance measurement requirements, special training methods, data reduction, artifact removal, data analysis and data interpretation. At a minimum, NTI would:
1. Assist in the writing of the Research Protocol.
2. Create special scenarios for performance measurement after A-LOC. These may include measures of situation awareness.
3. Validate all performance measures and systems for correct operation.
4. Reduce, analyze and interpret the simulator data.
5. Write report of research findings.

Period of work:    10-20 weeks

46

## Concept 5 - Upgrade of simulator to Windows 95 (F-PASS Version)

NTI is upgrading the flight simulator for application to a drug certification test battery (F-PASS) for AF. This includes integration with the Windows 95 operating system with eventual operation under Windows NT. The new version uses Microsoft Flight Simulator terrain databases that are modeled on actual geography throughout the world. In addition to the realistic terrain, the new version will contain aeromodels for T-38, and T-1 aircraft. The simulator will also operate with other Windows applications if needed.

*Workplan*
1. Purchase two CPU upgrades ($1000) and two graphics accelerator cards ($250).
2. Purchase two Windows95 OSs and install them on the centrifuge and training computers.
3. Modify the F-PASS version of the software to take its input from A/D converter instead of the game card. The existing A/D modules may have to be rewritten in Direct X to work in the Windows 95 environment. The same is true of the D/A conversion of +Gz for control of the centrifuge.
4. Rewrite the graphics for the "highway in the sky" in Direct X for Windows 95.
5. Port the scenario editor from the DOS version to operate with the new Windows 95 terrain database.
6. Validate all performance measures and systems for correct operation.

Period of work:                    4 weeks


## Concept 6 - Assessment of laser protection visor under G forces

The new laser eye protection comes in the form of spectacles that are supported by the bridge of the nose. Because of the spectacles light blocking qualities, they may distort some of the HUD information. Two major questions need to be answered:
1. During high G turns, does the laser protection system become displaced and affect mission flying performance? If it does shift, how much?
2. Do laser protection, G forces and the aircraft HUD interact to degrade pilot performance?

The first question can be answered with standard centrifuge performance testing including the use of the centrifuge flight simulator. The second question expands the experiment by inserting an actual aircraft HUD between the subject and the simulator's out-the-window (OTW) display. The technical problem of this effort would be to separate the simulator's HUD output from the display of the instruments and the OTW scene. The simulator's HUD information would be displayed through an F-16 or other aircraft HUD. The remaining simulator display would use standard graphics output for the OTW view as well as radars and instruments. The two questions are summarized in the following two research objectives.
1. Test the physical effects of the new laser eye protection on flying performance under G.
2. Test the readability of the HUD symbols with and without the new laser protection under different G levels.

In both cases the evaluation criteria would be the piloting performance measures from the F-16 flight simulator. For both approaches, OEO would provide the laser eye protection system.

*Workplan Question 1*
NTI would:
1. Write the Research Protocol.
2. Create special scenarios to answer the research questions.
3. Validate all performance measures and systems for correct operation.
4. Reduce, analyze and interpret the simulator data.
5. Write the report of research findings and present them at the ASMA convention.

Period of work:                12 weeks


*Workplan Question 2*
The government would provide the AF HUD, mount it in the gondola and provide the appropriate connections to the output of the simulator computer. In addition to the items of Workplan 1, the contractor would:
1. Interface the HUD to the simulator computer through the appropriate interface hardware.
2. Make the AF HUD selectable as an option when pilots are trained or tested.

Period of work:                9-12 Months

Concept 7 - Improved graphics display

The current simulator displays could be improved in several ways to add more realism. However, since the projector system in the gondola is currently at its maximum, a new projection system would have to be purchased to implement any of the following approaches.

1. Displays can be improved by using a higher resolution graphics card. This approach would improve the display of the current simulation world of SAFTE.

2. The software could be ported to an SGI computer. This approach would be very expensive.
   - It would require the purchase of an SGI computer, the A/D converter and D/A converter.
   - It would require the rewriting of the real-time executive, the graphics calls, the A/D and D/A modules; in short, a rewrite of most of the system.

Another version of this approach would be to add an SGI computer for the graphics capabilities alone. This would require much less expensive software rewriting. However, there is little room in the gondola for another computer. In our opinion, little would be gained porting to an SGI machine unless it would be important for other reasons.

3. The displays would be improved dramatically by porting SAFTE to the Windows95 or NT operating system (see Concept 5) similar to F-PASS. Because the F-PASS will use the Microsoft Flight Simulator terrain databases, graphics resolution will be improved over the current SAFTE system. Additional fidelity has also been added to F-PASS's representation of the cockpit, instruments, and HUD. This approach would be the best value because the Microsoft Flight Simulator terrain databases are modeled on actual geography throughout the world. A higher resolution graphics card would also be required.

*Workplan for Approach 3*
1. Purchase a new projection system with greater fidelity (Sharp LCD, Model 3000, 1024x768 resolution, XGA, super bright) and two high resolution graphics cards.

2. Government installation of all hardware.
3. Complete all work from Concept 5.
4. Validate all performance measures and systems for correct operation.

Period of work:             8 weeks

## Concept 8 - Network the SAFTE/centrifuge system

The idea of this concept is to integrate the scenario events taking place within the gondola with other networked simulation/training systems or models such as those running in the AESOP or Tac-Air Soar. All systems operating in this environment need to be DIS compliant at a minimum. This allows each "player" to "see" a representation of the other constructed or virtual players, their movements in space and their actions. It is also possible to talk to each other as well.

The basic work to allow SAFTE and the centrifuge pilot/subject to be compatible would require a basic network card ($150.00) and considerable work on programming the interface. Assuming that this would not be attempted until SAFTE was converted to Windows95, the emphasis would be on creating compatible spatial coordinate systems. Windows95 and NT contain the necessary network drivers and Mäk Technologies (185 Alewife Brook Parkway, Cambridge, MA 02138, (617) 876-8085) has ready-to-use DIS/HLA interfaces for the PC ($3500.00).

The other work required involves improving the bandwidth from gondola to the outside world. The current slip rings are noisy and bandwidth limited. A senior design project of students under the direction of Dr. James Frazer entitled "Improvement of the instrumentation/data acquisition of the centrifuge gondola using a telemetry system," 1997, describes a fiber optic solution for approximately $6400. The estimated price is low because it does not include thorough testing of the installed products. However, the price is a good estimate of the hardware required and the labor to install it. Since most of the testing would be completed by government engineers, these labor costs are not included in this proposal.

Should this enhancement to the centrifuges functionality progress to the level of participation in a large distributed simulation without the participation of the AESOP laboratory, a T-1 line would have to be installed and supported. This communications link is a very expensive to maintain. It is recommended that any efforts involving distributed simulation be coordinated with the AESOP facility since it should have a supported, secure, T-1 line in the near future.

*Workplan (assumes Concept 5 has been completed)*
1. Purchase a network card, a fiber optic telemetry system and the development tool kit for the DIS interface.
2. Government installation of all hardware.
3. Program SAFTE simulator system for DIS compatibility.
4. Validate all performance measures and systems for correct operation.

Period of work:             12 weeks

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**APPENDIX 1**

**DESCRIPTION OF THE SAFTE SYSTEM SOFTWARE**

The descriptions of the particular portions of the simulation software have been broken down functionally into input functions, processing functions, and output functions. Please note that files, if not explicitly stated, lie within the DATA directory underneath the directory containing the SIM.EXE program.

Inputs

The following are inputs to the simulation program. Some of these inputs are only referenced at initialization of the program while others are sampled continuously. Along with each input source is a description of the processing associated with the input.

1.  Configuration file (RTCONFIG.DAT) - This is a text file containing user configurable parameters. Of the various parameters such as parallel and serial port values, one of the most important is the system timer value, discussed at the beginning of the hardware section of this document. The system timer's value affects several aspects of the simulation program's behavior. The RTCONFIG.DAT file is read once at the beginning of the program.

2.  ThrustMaster parameter file (TMCAL.DAT) - This text file is automatically generated by the CAL.EXE program and specifies various parameters of the roll, pitch, rudder, and throttle axes which are used to characterize the control inputs for the F-16 model. This file is read once at the beginning of the program.

3.  Scenario database file (SCENARIO.DAT) - This file contains the declarations of all objects within all of the scenarios which are available, including way points, aircraft, SAM sites, triggers (see below), and input files associated with the scenarios. Once a particular scenario is specified, this file is opened and the information for the scenario is read into memory. All aspects of each scenario except the scenario control instructions are contained within this file.

4.  F16 trim files - The F16 model, like all true aerodynamic models, requires its initial internal state to be properly configured and cannot just be 'turned on' in an arbitrary state. To accomplish this, each scenario begins by reading into the F16 model a state statement from a trim file. Listing 1 of the appendix is a trim file (TRIM.DAT) and various files of the form SCENxx.DAT. A SCENxx.DAT file (referred to in the SCENARIO.DAT file) is read into the TRIM.DAT file at the beginning of a scenario, then the TRIM.DAT file is read into the F16 model to initialize it's state.

5.  Analog inputs (pitch, roll, rudder, and throttle) - The analog control inputs come from the ThrustMaster controls and appear at the game card input registers as signals to be measured by the software. As mentioned before in the hardware section these control inputs appear as pulses which are high for a period of time proportional to the physical position of the control. The software converts this pulse length into a normalized value by timing the length of the pulse then using the parameters in the TMCAL.DAT file to scale it. It will be noted that the analog input conversion takes place as a real time task. This is for two reasons: First, it allows the inputs to sampled at a precise rate.

Second, because software timing loops by definition cannot be interrupted, the task is assured to be accomplished in the real time loop without being interrupted.

6. Keyboard and HOTAS inputs - Keyboard and HOTAS (Hands-On-Throttle-And-Stick) inputs are in most cases character inputs which are generated by or come through the keyboard and are processed as they occur via a keyboard interrupt routine. Valid keyboard entries are detailed in the appendix of the "SAFTE Users Guide" document and define commands for events such as way point selection, raising and lowering the landing gears, and exiting the program. Controls from the throttle and stick (not counting the analog ones and certain exceptions) define such operations as HUD mode selection, speed brake engagement, weapons release, and air-to-air designate cursor movement. The exceptions are certain controls that can be defined as binary (1/0) values and are accessed through the game card interface. These inputs are converted to the same format inside the program as the character inputs.

7. Floppy disk - For applications where an automated sequence of scenarios is desired a special file named SAFTE.DAT residing on a floppy disk contains information on the history of scenario execution. When the program is started this file is read and information regarding the current scenario, scenario number and scenario history is copied into the program's memory. This information is used both to access the correct scenario in the scenario database and to create the name of the file on the hard disk to which data will be logged.

Processing of Scenarios

Start of Scenario

Processing within the simulation starts with accessing data for the selected scenario from the scenario database and creating the data file which will hold the data taken during the scenario's execution. All simulation objects are created and initialized and the correct trim file read into the F16 model. All initial conditions specific to the scenario (such as number of chaff rounds, landing gears up or down, ILS mode enabled or not) are set and the aircraft is released to fly.

The F-16 Model

As the scenario progresses, inputs from the controls are continuously measured, scaled and normalized, and fed to the aircraft model. The model takes not only the roll, pitch, rudder, and throttle values, but also the value of the speed brake and the position of the landing gears as inputs. The model uses these to simulate takeoffs, landings and free flight.

The output of the model consists of the output state vector. The output vector provides information on position, velocity, attitude, angle-of-attack and other parameters. This information is made available to the simulation system and is also shipped across the parallel interface to the graphics computer along with other information.

## Triggers

In order to control events during the course of a scenario (such as launching enemy aircraft or putting up an SA probe question) a device called a trigger is used, so called because its operation is triggered by events or conditions within the simulation. A trigger is a set of user defined code segments which have the following structure. Each code segment is open-ended and can accommodate an arbitrarily complex set of instructions:

A. Conditions - A set of instructions which specify under what conditions the trigger is active. The Conditions instructions return a value specifying True if the conditions are satisfied and False if they are not. The Conditions instructions are evaluated continuously unless the trigger has been disabled.
B. Initial Positive - A set of instructions which are executed when the Conditions go from False to True.
C. Positive - A set of instructions which are executed while the Conditions are True.
D. Initial Negative - A set of instructions which are executed when the Conditions go from True to False.
E. Negative - A set of instructions which are executed while the Conditions are negative.

In addition, to the above functions, triggers can have the following specifications:

A. Execute the trigger a set number of times or repeatedly.
B. Evaluate the trigger only during a user defined mode.
C. Evaluate the trigger only in the vicinity of a certain region of the terrain.
D. Initialize the trigger to be active or inactive. Triggers are not executed or have their conditions evaluated unless they are activated.

## Simulation Objects

There is currently a limited set of simulation objects supported by the program. These objects are entities created at the beginning or during the course of a scenario which can interact with the pilot and with each other in non-intelligent or semi-intelligent ways. These objects include the following:

A. The pilot's aircraft - This object includes the F-16 model along with speed brakes, landing gears, and other instrumentation. The pilot's aircraft appears to the simulation like any other object in the simulation.
B. Other aircraft - Semi intelligent objects possessing radar systems and weapons.
C. SAM sites - Semi intelligent threat centers capable of launching SAMs.
D. AAA sites - Semi intelligent threat centers like SAM sites.
E. Bombs - dumb objects created and launched by the pilot's aircraft or other aircraft.
F. SAMs and AAMs. These objects can be created and launched by SAM sites (for SAMs) or by the pilot and other aircraft (for AAMs).

Currently the pilot, other aircraft, and SAM sites are the only objects being used in the scenarios created to date. Support exists for the other objects both in the simulation and graphically on the graphics side, though some work still remains to make all objects fully functional.

Instrumentation

Along with the objects of the simulation is the set of simulated instruments. The instrumentation list includes the following:

A.  Radar Warning Receiver (RWR) - This instrument detects hostile radar sources and displays them on the RWR screen. Each type of threat has it own symbology and lethality parameters. When a new threat is detected by the RWR system a 'new guy' signal sounds alerting the pilot of the threat's presence and symbology appears on the screen placed in the direction of the threat and at a distance from the display's center based on the threat's calculated lethality. When no new threats are being processed the RWR emits a tone corresponding to the threat with the greatest lethality of the currently detected threats.

B.  Air-to-Air (ATA) Radar - The ATA radar displays returns of other detected aircraft relative to the pilot's current heading. The track ball and mouse button on the throttle allow movement of the ATA cursor and designation of a target to launch against. The symbology of the ATA radar includes the relative heading and altitude of all detected aircraft. For a designated aircraft additional information is displayed at the top of the display which includes: target aspect, target heading, ground speed, and closure rate. Additionally, new symbology appears on the ATA screen and the HUD screen indicating the missile's minimum and maximum ranges and the time to activation of the missile once the missile is launched.

C.  ILS system - During the time the landing gears are down the ILS symbology is displayed, if enabled. The ILS system consists of a simulated ILS beacon at the end of the airport and simulated equipment onboard the aircraft which directs the pilot to the approach glide slope of the runway. The ILS equipment consists of an angle-of-attack (AOA) bracket, ILS deviation bars, and a flight director. The deviation bars and the flight director symbology can be enabled or disabled based on the scenario designer's desires. Figure 1 of the appendix describes the various symbols of the ILS system.

D.  Other instruments - The remaining instruments include the following:

1.  Speed Brakes - located just under the HUD mode switch, the speed brake switch extends the brakes proportionally to the amount of time the switch is pulled toward the pilot, up to a maximum of 60 degrees (45 if landing gears are engaged). Pushing the switch away retracts the brakes to zero.

2.  Weapons release - The red button at the top of the flight stick releases bombs and launches missiles. If in AAM mode a 'time to active' message will be displayed on the ATA radar screen once a missile is launched.

3.  Counter measures - Chaff and flares can be selected by toggling back and forth with the 't' key on the keyboard. The paddle switch at the base of the flight stick releases two (2) bundles of chaff or two (2) flares each time it is pressed.

Outputs

Output from the simulation program goes to one of three places: the screen, the parallel port and the hard disk/floppy disk. Of the three destinations the parallel port is the most heavily used, followed by the hard disk, then the screen and floppy disk. Following is a description of the information content of each path.

Screen - The screen is the least used path mainly because most of the user interface comes from the graphics side of the system; nevertheless, the simulation side must communicate to the user such things as queries for information and notice of scenario completion. The simulation side is also where the scenario is initialed by typing "SIM" at the DOS prompt.

Floppy disk - For applications where an automated sequence of scenarios is executed the floppy disk contains information about the execution history of the scenarios. At the end of each scenario this information is updated in preparation for the next run.

Hard disk - At the beginning of each scenario a file is opened with a unique name on the hard disk in preparation for data logging. As data is logged it is recorded in the file according to the formats specified in Diagrams 2a and 2b of the appendix. When the file is first opened an LDF record is written to the file. Subsequent data records (OUTvect, INPUTvect, CHARvect, Savect) are then written preceded by an LDH record which specifies the type and size of the record immediately following it. For more information on data logging see the appendix here and in the "SAFTE Users Guide" document.

Parallel Port - The parallel port data can be broken down into three types occupying three sections in the parallel port data vector: aircraft output vector, navigation/ILS information and messages. Note that the contents of the data vector is transferred at a preset rate as defined by the system timer and information in the RTM.DFN file and is not driven by the data itself (see diagram 3 in the appendix for details on the .DFN files).

    A. F-16 output vector - This vector contains the complete output vector from the F-16 model and is passed in its entirety to the graphics machine. The appendix of the "SAFTE Users Guide" document details the contents of the output vector.

    B. Navigation/ILS information - This information contains data on the position of the current way point and target point as well as ILS symbology data. This data is sent this way and not as a message (see next item) because it must be continuously updated and displayed. Diagram 4 of the appendix gives details of the data vector's contents.

    C. Messages - This is a section where messages going to the RWR, the ATA radar, the instrument displays and other destinations are written. The messages are multiplexed through the message area with each message having its own ID number and sub ID number which is used within the parallel port interrupt routine on the graphics side to route the message to its correct destination. Another routine on the graphics side scans the different message destinations and keeps the graphics system updated with the latest information.

Scenario End

A scenario can be ended in one of several ways:

    A. The ending conditions are reached or the pilot lands the plane successfully.
    B. The pilot crashes the plane.
    C. The pilot runs out of time in the scenario (the maximum time of each scenario is programmed into the scenario).
    D. The pilot aborts out of the scenario for some reason.
    E. The computer hangs or crashes.

Each of these endings is reflected in the name of the data file when it is updated at the end of the scenario. The appendix of the "SAFTE Users Guide" document lists the ending values for each condition and the format of the data file name.

Graphics System Software

The graphics program is only responsible for the creation and presentation of graphics information. No simulation control or processing of inputs takes place in the graphics computer, as that is the function of the simulation computer.

The primary functions of the graphics system are:

A. Display of the Out-The-Window (OTW) view.
B. Display and update of the F-16 HUD
C. Display of other instrumentation (speed brakes, power setting, etc.)
D. Display of messages (SA probes, etc.)

Inputs

Several inputs to the graphics program are similar to those of the simulation program while others (e.g. the terrain database) are unique to this system. Following is a description of each of the input sources. If not explicitly specified, all input files are to be found in the DATA sub-directory:

A. RTCONFIG.DAT - This file does for the graphics system exactly what it does for the simulation system; it provides parameter information for the RTK exec, the most important value being the system timer value.
B. MESSAGE.DAT and .TXT files - These file are for the display of messages such as SA probes. The MESSAGE.DAT file contains a list of all message files used by the scenarios. The .TXT files contain the actual messages.
C. Miscellaneous .DAT files - Files like SAM.DAT, AC.DAT, etc. are data files used for displaying various objects in the OTW view.
D. Keyboard inputs - The graphics system does not rely on keyboard input to the degree that the simulation system does. The major keyboard interactions are to execute the program 'GRAPHICS.EXE' from the DOS command line and to quit the program via the 'Q', 'q', 'X', 'x', or 'ESC' keys.
E. Aircraft output vector - The output vector of the aircraft is shipped to the graphics side at a constant rate determined by the system timer value and the contents of the RTM.DFN file on the simulation side. Within the output vector are values needed to drive the HUD display and the OTW view. Each receipt of a new parallel port transmission engages the parallel port interrupt handler which transfers the output vector to it's proper place in memory.
F. Navigation/ILS data - Within the data vector transmitted during each parallel port transmission is information on way points, targets, and ILS displays. This data is used to drive additional instrumentation located on and off the HUD.
G. Messages - At the end of the parallel port data vector is an area devoted to message transmission. To this area is written data designated for different systems on the graphics side. Each packet of data contains a major and a minor ID which tells the graphics software which system the data is targeted for. When a parallel port

transmission is received the interrupt handler on the graphics side decodes the destination of any existing message and routes the data to it's appropriate place. Data sent in this fashion is necessarily multiplexed as there is only one message area. This quite acceptable for data which is infrequent in nature.

Processing

As in the simulation system, the RTK presides over the execution of the real time task list and the background task list. One significant difference between the two systems is the predominance of background tasks in the graphics system. The only real time task currently on the graphics side is the maintenance of signals used for blinking various displays.

The graphics processing can be divided into the following sequence of operations. This is the order in which data is received by the system and converted into graphics displays:

A. Output vector and message parsing - Messages and the contents of the aircraft output vector are processed by the parallel port interrupt handler and distributed to their respective memory locations. Within the background processing is a routine called Update which processes the received information. Update looks for new data and executes code which utilizes the data. Examples of this kind of processing include SA messages, RWR and ATA radar target lists, and starting and stopping the graphics processing.

B. OTW view - After messages have been parsed the graphics processor proceeds to create the out-the-window view. The OTW view includes the following sequence of drawings:

1. Sky - The color of the sky is set according to the conditions of the scenario: day/night, clear/cloudy.
2. Moon and stars - If the scenario is a night mission the moon and stars will be drawn on top of the sky.
3. Horizon - The OTW processing first displays an infinite horizon on which is drawn the rest of the scenery. The color of the horizon is derived from the color of the playing field terrain.
4. Terrain - The ground, including all flat objects such as rivers, roads and airfields but not including mountains is drawn on top of the horizon and sky.
5. Mountains and all non-flat objects including light sources are next drawn on top of the flat terrain. Processing is done in this order due to the use of a modified version of the painter's algorithm which is fast but subject to certain limitations.

C. HUD - The HUD symbology is driven by the contents of the aircraft output vector. As new data is transmitted over the parallel link the HUD display is updated to reflect the changes. The HUD is drawn on top of the OTW.

D. RWR - The radar warning receiver (RWR) is displayed along with the ATA radar display but after the HUD. Information for the RWR comes from a list of targets transmitted to the graphics side in a message once every three seconds.

E. ATA radar - The air-to-air radar is displayed along with the RWR display but after the HUD. Information for the ATA radar comes from a list of targets transmitted to the graphics side in a message once every three seconds. Included in the ATA display is the relative position of each return along with it's altitude. Designated targets are circled and additional information is displayed at the top of the display including target aspect angle, heading, ground speed, and closing rate. Additionally,

a missile minimum and maximum range scale appears for launch purposes both in the ATA display and on the HUD. When a missile is launched the time to activation is displayed at the bottom of the ATA display.

F. Cockpit and instruments - The cockpit, represented by a gray background behind and between the RWR and ATA radar displays, contains various instrumentation displays including speed brake position, throttle position, landing gear status and countermeasures information. The data for most of these displays comes from one or more messages sent from the simulation side.

G. Text messages - When SA probes or other messages are to appear on the graphics screen a message is sent over from the simulation side specifying which message to show and how it is to be displayed. The message itself is stored on the graphics side in the DATA sub-directory and an index of all available messages is stored in another file in the same directory by the name of MESSAGE.DAT. The number of the message is used to look up in MESSAGE.DAT the file name of the text message. After getting the file name the file is opened, the graphics screen is blanked, and the text of the message is displayed.

System Interface

The software interface consists of two interrupt handlers which utilize a custom handshaking procedure to transfer data across the interface. When data is ready to be transferred from the simulation system to the graphics system, the simulation system signals the graphics handler and causes the graphics system to be interrupted. The graphics system then signals the simulation system that it is ready and causes the simulation system to enter it's interrupt handler as well.

When both systems' handlers are active another level of handshaking is initiated and data is then transferred byte by byte from the simulation side to the graphics side. At the completion of the transfer further handshaking signals the end of the transfer and both system exit their handlers. Currently only transfers from the simulation side to the graphics side are supported.

The various Listings, Figures, and Tables on the next several pages will aid the reader in understanding the text presented above.

```
BKG.DFN
RTCONFIG.DAT
RTM.DFN
SCEN1.DAT
SCEN2.DAT
SCEN25.CUR
SCEN25.DAT
SCEN3.DAT
SCEN37.DAT
SCEN40.DAT
SCEN49.DAT
SCEN5.DAT
SCEN55.DAT
SCEN71.DAT
SCEN75.DAT
SCEN99.DAT
SCENARIO.DAT
TMCAL.DAT
TRIM.DAT
UNUATTD1.DAT
UNUATTD2.DAT
UNUATTD3.DAT
UNUATTD4.DAT
```

Listing 1.1
Simulation Data Files

```
AAA.DAT
AC.DAT
BKG.DFN
BOMB.DAT
MESSAGE.DAT
MISSILE.DAT
MSG????.TXT
RTCONFIG.DAT
RTM.DFN
SAM.DAT
SCENAR??.TXT
STARS.DAT
TERRAIN.DAT

Note: ? = wildcard
```

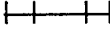Listing 1.2
Graphics Data Files

| | |
|---|---|
| | Flight Path Marker - ILS Beam OK |
| | Flight Path Marker - No ILS Beam |
| | Horizontal ILS Dev. Indicator |
| | Vertical ILS Dev. Indicator |
| | Angle of Attack Bracket |

Figure 1.1
ILS Symbols

```
td_TCNT:        // Timer  Count Value Record
    w:          unsigned integer,4 bytes          // Timer Count Value

point:                  // "Point" Record
    X:          integer, 2 bytes                  // X coordinate
    Y:          integer, 2 bytes                  // Y coordinate

Rtim:           // RTK System Time Record
    cyc_num:            unsigned integer, 4 bytes     // Cycle Number
    frame_num:          integer, 4 bytes              // Frame Number
    subframe_num:       integer, 4 bytes              // Sub-frame Number
    TMRcnt:             td_CNT, 4 bytes               // Timer Count Value

EventRecord:    // RTK Queue Record
    what:       integer, 4 bytes                  // Event Type
    message:    integer, 4 bytes                  // Type Dependent Information
    linkcnt:    integer, 4 bytes                  // Event Link Byte Count
    when:       Rtim, 16 bytes                    // RTK Sys Time since RTK launch
    where:      point, 4 bytes                    // Mouse Location at Event
    modifiers:  integer, 4 bytes                  // Keyboard Modifier Flags

TStamp:         // Time Stamp Record
    esecs:      unsigned integer, 4 bytes         // Elapsed Seconds
    fract:      float, 4 bytes                    // Fractional part of seconds
```

Diagram 1.1

Basic Data Record Types

```
LDFhdr:                     // Log Data File Header Record
    frame_mult:     unsigned integer, 4 bytes     // Frame Multiple
    timer_cnt:      unsigned integer, 4 bytes     // Timer Count

LDBhdr:                     // Log Data Block Header Record
    type: integer, 4 bytes                        // LogData Block Header Type
    cnt:  integer, 4 bytes                        // # of bytes to follow in Block

OUTvect:                    // Aircraft Output Vector Record
    type: integer, 4 bytes                        // Type of Buffer
    t:              Tstamp, 8 bytes               // Time at Data Write
    Erec:           EventRecord, 36 bytes         // Time at Data Write
    X[25]:          float, 4x25 bytes             // Aircraft Data Vector

INPUTvect:      // Controls Input Vector Record
    type: integer, 4 bytes                        // Type of Buffer
    t:              Tstamp, 8 bytes               // Time at Data Write
    Erec:           EventRecord, 36 bytes         // Time at Data Write
    X[4]:           float, 4x4 bytes              // Controls Input Vector

CHARvect:       // Character Data Record
    type: integer, 4 bytes                        // Type of Buffer
    t:              TStamp, 8 bytes               // Time at Data Write
    Erec:           EventRecord, 36 bytes         // Time at Data Write
    X:              char, 1 byte                  // Character Data

SAvect:                     // SA Data Vector Record
    type: integer, 4 bytes                        // Type of Buffer
    t:              TStamp, 8 bytes               // Time at Data Write
    Erec:           EventRecord, 36 bytes         // Time at Data Write
    X[2]:           integer, 4x2 bytes            // Aircraft Data Vector
```

Diagram 1.2

Data Logging Record Formats

```
[Procedure Name]     [Frame Mask] [Module Mask]

Frame Mask - 16 bit number, each bit of which if set to 1 enables the
procedure for that frame

Module Mask - 16 bit number, each bit of which if set to 1 enables the
procedure for that module type

Note: One frame is one clock pulse of the system timer interrupt
```
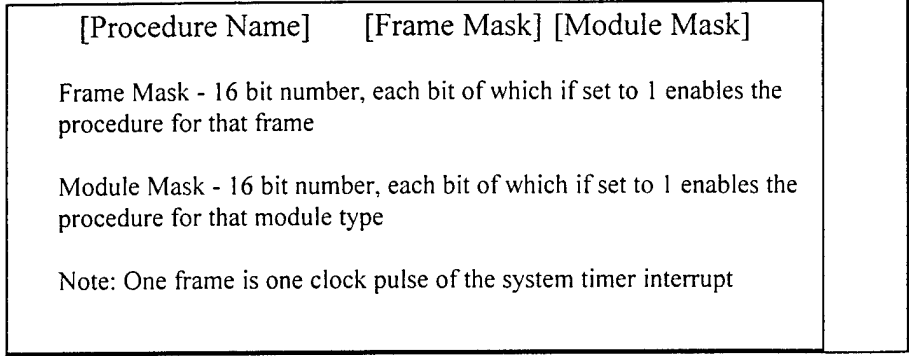
Diagram 1.3
.DFN File Format

| Aircraft Output Vector |
|---|
| (See SAFTE Users Guide appendix for contents) |
| Start Byte 1 — Stop Byte 100 |

| Bearing to Target or Way Point |
|---|
| Start Byte 101 — Stop Byte 104 |

| Distance and Time to Way Point |
|---|
| Start Byte 105 — Stop Byte 108 |

| Current Way Point Position / Slant Angle for CCIP Mode |
|---|
| Start Byte 109 — Stop Byte 120 |

| Current Target Position (AAM & CCIP Modes) |
|---|
| Start Byte 121 — Stop Byte 132 |

| Current Pipper Position for CCIP Mode / Slant Range of Desigated Target / ILS Deviation Bar Data |
|---|
| Start Byte 133 — Stop Byte 136 |

| Slant Angle of Desigated Target / ILS Flight Director Data |
|---|
| Start Byte 137 — Stop Byte 144 |

| Start of Message Buffer Area / Message ID |
|---|
| Start Byte 145 — Stop Byte 148 |

| Message Buffer (Continued) |
|---|
| Start Byte 149 — Stop Byte 264 |

Diagram 1.4
Data Vector Contents

| Aircraft Output Vector |
|---|
| (See SAFTE Users Guide appendix for contents) |
| Start Byte         Stop Byte |
| 1         100 |

| Bearing to Target or Way Point |
|---|
| Start Byte         Stop Byte |
| 101         104 |

| Distance and Time to Way Point |
|---|
| Start Byte         Stop Byte |
| 105         108 |

| Current Way Point Position / |
|---|
| Slant Angle for CCIP Mode |
| Start Byte         Stop Byte |
| 109         120 |

| Current Target Position |
|---|
| (AAM & CCIP Modes) |
| Start Byte         Stop Byte |
| 121         132 |

| Current Pipper Position for CCIP Mode / |
|---|
| Slant Range of Desigated Target / |
| ILS Deviation Bar Data |
| Start Byte         Stop Byte |
| 133         136 |

| Slant Angle of Desigated Target / |
|---|
| ILS Flight Director Data |
| Start Byte         Stop Byte |
| 137         144 |

| Start of Message Buffer Area / |
|---|
| Message ID |
| Start Byte         Stop Byte |
| 145         148 |

| Message Buffer (Continued) |
|---|
| Start Byte         Stop Byte |
| 149         264 |

Diagram 1.4
Data Vector Contents

| Message Name | ID |
|---|---|
| Start/Stop | 1 |
| Number of Graph Objects | 2 |
| SAM Site Object | 3 |
| AAM Site Object | 4 |
| Enemy Aircraft Object | 5 |
| SAM/AAM Object | 6 |
| Bomb Object | 7 |
| RWR Display | 8 |
| ATA Radar Display | 9 |
| Instrument Displays | 10 |
| Text Message | 11 |
| HUD Mode, etc. | 12 |

Table 1.1
Message Types

[X Position] [Y Position] [Text Message]

| Coordinate Ranges | Min. | Max. |
|---|---|---|
| X Position | 0 | 639 |
| Y Position | 0 | 479 |

Table 1.2
Text Message Format

# APPENDIX 2

## SAFTE SYSTEM CONFIGURATION

The SAFTE system physically consists of two Pentium computers connected to each other via the parallel port of each machine. Due to the computationally intensive natures of the F-16 aerodynamic model and the out-the-window graphics the graphics functions are run on one machine and the aircraft and scenario simulation on another. For effective real time system performance the graphics machine runs at 120 MHz or better with 16 MB of RAM and VESA 640x480x256 color graphics support. The simulation machine runs at 90 MHz or more with 8 MB of RAM and at least 540 Mbytes of hard disk space to store data logged during scenario execution. The peripheral equipment consists of one of each of the following: ThrustMaster throttle, rudder, flight stick, and game board.

SAFTE provides continuous time stamped disk logging of control input data at 5 Hz, aircraft state vector information at 1 Hz, and keyboard and other pertinent data as they occur. To achieve sub millisecond time stamping accuracy in real time a custom real time kernel (RTK) operating system provides both precise event timing and access to system resources. With the RTK real time operation of the F-16 aerodynamic model as well as other simulation entities is provided for.

The aircraft state vector consists of 29 different quantities including the position, attitude, velocity and angle of attack (AOA) of the aircraft. The control inputs include roll, pitch, rudder, and throttle values. Other inputs include keyboard and hands on control entries.

Along with pilot inputs various events are also logged, including SA queries, simulation control events and radar activity.

The continuous time stamped logging of the above data items forms a small but essential set of raw information from which a wide variety of statistics can be computed.

### Use of Utilities for the SAFTE Centrifuge Project

The programs comprising the SAFTE centrifuge project are as follows:

1. SIM.EXE - The simulation program.
2. PROFILE.EXE - A program for generating flight paths.
3. HISTORY.EXE - A report generating program for data analysis.

The purpose of these programs is to allow the user to exercise subjects using predefined flight paths, collect data from the subjects, and create reports in a format suitable for reading or import into a spreadsheet or other analysis tool. Following are details on the operation of each program.

### SIM.EXE

The SIM program is the main simulation utility. The simulator contains an F16 model along with a HUD and other instruments on the screen. Once the necessary preliminary data is entered, the simulator is started and controlled by the force stick and its button inputs. Gz is sent to the

centrifuge to drive it's operation and data is collected during the flight which is written to the hard disk at the end of the run. The simulator is exited by pressing <ESC> on the keyboard.

To access the simulation, start the simulation computer and at the C:\ prompt, type "z" and <enter>. This places the user in the main simulation directory. It is very important to follow this step and to not simply change to the simulation directory instead. Several important path assignments are made via this procedure. The startup command "z" may be changed as necessary.

To begin the simulation, type "sim s" and <enter>. The user will be prompted to enter an ID number. This number is stored in the file IDS.DAT in the SAFTEDAT sub-directory and can be changed by the user. Currently the numbers "123" and "999" reside there.

After the ID is entered the program will prompt the user for a scenario number. To execute the predefined flight paths enter "97". The screen will display a message stating the purpose of the scenario and wait for a key to be pressed. Once a key press occurs the simulation begins.

Following are the functions supported by the simulation and how to access them:

> Pitch and Roll - Accessed by pressure on the force stick.
> Throttle - Pushing the center lever up increases power, pushing down decreases power.
> Landing gears - The right button on the force stick toggles the gears, as well as "l' on the keyboard.
> Trigger Button - The front button on the force stick is for specialized user input.
> Way Points - The left button on the force stick toggles to different way points.
> Recording - The "r" key on the keyboard toggles recording of flight path status - See PROFILE below.
> Exit - the <ESC> key on the keyboard terminates the program and saves all collected data.
>
> NOTE: the Caps Lock on the keyboard must be OFF for proper operation of controls.

Once the simulation has ended, control, status and performance data are stored in a uniquely named file in the main simulation directory. The first two characters of the file name represent the scenario number and the file name extension represents the subject ID.

PROFILE.EXE

The PROFILE program is used for generating predefined flight paths. These flight paths are presented to the subject as a "rope in the sky" consisting of "hoops" to fly through. The flight paths can consist of combinations of five styles:

1. Straight - A line in space for a given number of seconds at the current speed.
2. Left/Right turn - A level turn from the current heading at a given Gz value and for a given number of degrees.
3. Up/Down turn - A vertical turn from the current altitude at a given Gz and for a given number of degrees.

The flight path is generated from a profile stored in a user created file. Each line in the file contains a command. The file starts with the key word "start" and ends with the key word "stop". Following is an example profile illustrating the syntax of the commands:

```
start
straight 10.0
left 2.0 90.0
straight 10.0
right 3.0 90
straight 15.0
up 2.0 45.0
down 2.0 90.0
up 2.0 45.0
straight 10.0
stop
```

This file would generate a profile consisting of 10 seconds in a straight line, a left turn at 2 Gs for 90 degrees, a straight run for 10 seconds, a right turn at 3 Gs for 90 degrees, straight for 15 seconds up at 2 Gs to 45 degrees, over and down at 2 Gs to -45 degrees, an up turn at 2 Gs to level off and a final straight segment for 10 seconds.

Before running the PROFILE program a trim file must be created for the aircraft. This tells PROFILE what the starting speed, altitude and attitude of the aircraft will be. To create this file start the simulation and execute the scenario "99". This is a generic scenario allowing the user to fly the plane to the position desired for the start of the profile. When the starting conditions are achieved toggle the recording mode of the simulation by pressing the "r" key, wait 1 - 2 seconds, then press it again. The necessary data will have been recorded in the correct file.

After the trim data has been generated, type "profile <filename>" from the main simulation directory where <filename> is the name of the user created profile file. The newly generated data will be placed in the correct file for future use.

If needed, a complete profile set can be archived by backing up the user created profile file and the files HISTORY.TRM and HISTORY.DAT in the DATA sub-directory. Note that each profile generation overwrites the contents of these two files so backing up these files is necessary if the profile is to be saved for future use.

HISTORY.EXE

The HISTORY program generates a report file from the generated profile data and the collected simulation data. HISTORY attempts to match each recorded position of the aircraft with the nearest hoop in the prerecorded flight path. The report file is in text format and includes on each line the following information:

1. Time into scenario
2. Miss distance from the hoop
3. Type of hoop (straight, left turn, up, etc.)
4. Set number of hoop (first straight set, second left turn set, etc.)
5. Index into the current set (first hoop, second hoop, etc. in this set)
6. Gz value of the hoop
7. Event value - currently represents Trigger value (1 - pressed, 0 - released)

To execute the HISTORY program type from the main simulation directory:

history <report name> <data file name> [<profile data file name>]

The report name is the name of the report file. The data file name is the name of the simulation data file and can be found by examining the contents of the main simulation directory. The profile data file name is optional and allows a custom profile data file name and path to be entered.

## SAFTE DATA LOG DESCRIPTION

To understand the contents of the data log files some explanation of their generation should be given. When any program constructed using the Real Time Kernel (RTK) process is executed, the RTK replaces the PC's system timer interrupt (INT 8) with it's own interrupt routine. While this allows the real time processing of user defined tasks it also means that the DOS time-of-day clock is disabled and thus the DOS clock will be retarded by the length of time the program is running (unless some provision is made to update the clock during or after execution).

The PC's timer counts down at a rate of 1193180 Hz. To use the timer a value from 0 to 65535 is loaded into the timer's register. The timer automatically begins to count down and when a value of zero is reached an interrupt is generated and the previous value is reloaded into the counter. This behavior gives rise to a regular clock interrupt which for a counter value of 65535 occurs at a rate of 18.2 Hz, the familiar DOS system timer frequency.

Under the RTK system the counter value (and thus the timer frequency) becomes a user-defined quantity allowing the fine control of real time processes. For the current SAFTE system both the aero software and the visual software are programmed (via the file RTCONFIG.DAT) to generate a system clock interrupt at a 50 Hz rate. The value of the counter along with some additional data is recorded in the data log file.

Logging Record Types

There are three classes of records recorded in each data file.

These are:

    A. LogData file header records. These contain a number known as the frame multiple and the counter value used to generate the desired frequency of the timer interrupt. See LOG.H for details.

    B. LogData block header records. These records indicate the type and size of the next record to follow. See LOG.H for details.

    C. Data records. These records contain the actual simulation data. These records are further divided into four types as explained in the next section. Each data record is preceded by a block header record.

Data Types

There are four types of data recorded under the SAFTE system.

    1. OREC (typedef OUTvect) - output vector from the aero model. The definition of the vector values is found in the file F16.H.

    2. IREC (typedef INPUTvect) - control inputs from the pilot. This is an array of size four. The array elements in order are:

ROLL, PITCH, RUDDER, THROTTLE.

3. CHREC (typedef CHARvect) - character from the keyboard or ThrustMaster controls. See related information on control/keyboard input definitions.

4. SAREC (typedef SAvect) - general vector of SA information. This vector is for recording general information usually relating to SA data. The vector has two elements: a type field and a value field. The type specifies the type of SA data being collected and the value records the quantity being collected. See DPLUSR.H for definitions of the different SA types.

Data Record Formats

All four types of data records have a common format as seen from their definitions in FILTERS.H. This format is as follows:

A. Type - type of record (OREC, IREC, CHREC, SAREC)
B. Timestamp - another record recording the record's generations in seconds and fractions thereof.
C. EventRecord - a record comprised of subrecords which records system information as well as specific message information. The event record is used here to provide timing of the record's generation to the nearest tick of the clock (0.838 microsecs.).
D. Data Vector (or Scalar) - the last item in the record is the actual data being recorded. The data types have been covered in the previous section.

Data Recording Sequence

Each type of data record is logged under it's own specific conditions. These conditions are as follows:

A. ORECs - The aero state vector is record every second. The time between ORECs can vary by a few percent.

B. IRECs - The control vector is recorded five (5) times per second. Like the ORECs the IRECs may vary a few percent in inter-record timing.

C. CHRECs - Characters are recorded as generated so are asynchronous.

D. SARECs - SA events are recorded as generated so are asynchronous.

OUTPUT OF THE FILTER.EXE PROGRAM

To illustrate the above, the following text is a excerpt of the output of the filter.exe program as run on an actual data file:

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

frame mult: 1     <--- dividing factor; 1 = execute every interrupt

timer count: 23864     <--- timer count value 23864 = 50 Hz

TS     ET     TY     DATA
---    -------   -------   ---------

T: 1.33 (1.33), SAREC: (0(SIM_MESSAGE), 71) <--- SA type: message, data: msg 71

T: 1.44 (1.46), IREC: P:  0.8 R: -5.9 TH: 115.7 RDR: 9.7 <-- Control Inputs

T: 1.60 (1.62), IREC: P: -1.5 R: -6.9 TH: 115.7 RDR: 11.1

T: 1.84 (1.86), IREC: P:  0.0 R: -6.9 TH: 115.7 RDR: 11.1

T: 2.00 (2.02), P: (0.00, 0.00, 0.00)

T: 2.00 (2.02), IREC: P:  0.8 R: -5.9 TH: 115.7 RDR: 9.7

T: 2.24 (2.26), IREC: P:  0.8 R: -5.9 TH: 116.5 RDR: 12.5

T: 2.40 (2.42), IREC: P:  0.8 R: -5.9 TH: 115.7 RDR: 9.7

T: 2.57 (2.57), SAREC: (4(SIM_TIME), 1) <--- SA type: sim time toggle, data: start

T: 2.64 (2.66), IREC: P:  0.8 R: -5.0 TH: 115.0 RDR: 9.7 T: 2.80 (2.82), IREC: P:  0.0 R: -6.9 TH: 115.0 RDR: 11.1

T: 3.04 (3.06), P: (30.98, 134.19, 2.59) <--- position (NORTH,EAST,ALTITUDE)

.
.
.

T: 16.77 (16.77), CHREC: l (108) <--- l = raise/lower landing gear

.
.

T: 23.98 (24.00), SAREC: (0(SIM_MESSAGE), 7101) <--- message: msg7101

T: 23.98 (24.00), SAREC: (0(SIM_MESSAGE), 7101) <--- repeat

T: 23.99 (23.99), SAREC: (4(SIM_TIME), 0) <--- stop sim time

.
.

T: 25.96 (25.98), CHREC: H (72) <--- slider switch "yes" response to probe

T: 25.97 (25.97), SAREC: (4(SIM_TIME), 1) <--- start sim time again

T: 26.12 (26.14), CHREC: L (76) <--- return of slider switch to middle pos.

.
.

T: 35.20 (35.22), CHREC: w (119) <--- toggle waypoint

T: 35.20 (35.22), SAREC: (7(SIM_CUR_WP), 0) <- value of new WP (= 0)

T: 35.44 (35.46), IREC: P: 12.5 R: 19.6 TH: 84.5 RDR: 9.7

T: 35.52 (35.50), CHREC: w (119) <--- toggle waypoint

T: 35.52 (35.50), SAREC: (7(SIM_CUR_WP), 1) <--- value of new WP (= 1)

.
.

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

NOTES:

TS = Timestamp of data from the data record
ES = Elapsed time calculated from the EventRecord data in the data record
TY = Type of record (IREC, OREC, etc.)
DATA = data within the record (ORECs are partially listed)

IMPORTANT: It will be noted that certain SARECs are of the type SIM_TIME.

Because the simulation can be "frozen" at different times a record of the starting and stopping of "sim time" must be provided in order to calculate the elapsed time in the simulation. The timestamp of data is based on the elapsed time of the RTK and is independent of the time in the simulation.

MISCELLANEOUS NOTES:
   A.  All keyboard input is in lower case, all control button input is upper case. Refer to the file SAFTE.B50 to view the programming of the control buttons.
   B.  Each data file begins with a LogData file header record.
   C.  Each data record is preceded by a LogData block header.

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# APPENDIX 3

## <u>SAFTE EDITING TOOLS GUIDE</u>

This document describes the tools available for creating and modifying both the scenarios and graphics of the SAFTE system. These tools were developed for the initial generation of scenario and graphics databases and as such should be viewed as a work in progress. Some features of the tools are inoperative due to a continuing state of flux in the conceptualization of the database and some require a full development environment (i.e., compiler) to be used. This document will detail the use of the tools as they presently exist.

### Scenario Generator

The scenario generator provides for the creation and modification of scenarios. A scenario defines the starting point of the pilot's aircraft, what objects the pilot will encounter, and how the simulation will interact with the pilot. These items as well as others, which are transparent to the pilot, are specified in the file created by the researcher. The scenario creation process occurs in three steps: 1) use a text editor to create a scenario file containing the definitions of the elements of the scenario, 2) pre-compile the scenario file into a combination of a scenario database file and auto-generated C++ code modules, 3) recompile the simulation program to include the new code.

### Scenario File

The creation of a scenario starts with the creation of a text file which defines the elements of one or more scenarios. The overall format of a scenario file is as follows. Note that the spelling and capitalization of underlined keywords in the file is important. The file name is not important:

```
[Start of File]
Scenario: scenario_number
        .
        .
        .

Scenario: scenario_number
        .
        .
        .
[End of File]
```

In the above diagram the keyword Scenario: is followed by the scenario number. Each scenario in the file must have a unique number. The number of the first scenario can optionally be left off and the generator will assign it the number "0".

## Scenario Elements

Within a scenario there are certain objects which can be defined. The definitions will be stored in a database which will be read into the simulation at initialization and converted into actual simulation entities. The order in which objects are defined within the scenario is unimportant except for triggers which must follow all other definitions. The following is a list of definable objects within the file:

A.  Misc. Objects
    1.  Comments
    2.  File names
    3.  User points
    4.  Way points
    5.  SAM sites
    6.  AAA sites
    7.  Other aircraft
    8.  User defined modes
    9.  Number of bombs carried by the pilot

B. Triggers

## Object Syntax

The following is a definition of each object and the syntax for specifying it in the file:

A.  Misc. Objects

1.  Comments - Comments can be inserted anywhere in the file for explanatory or documentation purposes. To insert a comment a "//" anywhere in the line will cause it to be ignored by the generator.

2.  File names - One or more file names can be declared for use by the simulation for both reading and writing data. The declaration of file names is as follows:

    Files:
    file_name1_tag : file_name1
    file_name2_tag : file_name2
    file_name3_tag : file_name3
        .
        .

    The file name tag is a reference name comprised of letters and numbers up to 15 characters in length. Examples would be: F1, TrimFile, etc.. The tag is the name which will be used in the rest of the scenario. Following the colon ( : ) is the file name as it appears to DOS. Use "\\" instead of "\" to specify sub-directories (i.e., C:\\a\\data\\trim1.dat).

3. User points - User points define points in the simulation "world" which the user wishes to refer to. A good example of their use is in specifying the location of the ILS beacon of the runway. Following is the syntax for user points:

user_point1_tag : north_value (nmi) east_value (nmi) altitude (ft)
user_point2_tag : north_value (nmi) east_value (nmi) altitude (ft)
user_point3_tag : north_value (nmi) east_value (nmi) altitude (ft)
.
.

Each point has a tag name followed by the coordinates of the point. The altitude coordinate, if left off, defaults to 0.

4. Way points - Way points define the points along the way of the pilot's mission. Way points will be displayed by the navigation system upon activation. Following is the syntax for way points:

Way_Points:
way_point1_tag : north_value (nmi) east_value (nmi) altitude (ft)
way_point2_tag : north_value (nmi) east_value (nmi) altitude (ft)
way_point3_tag : north_value (nmi) east_value (nmi) altitude (ft)
.
.

Each point has a tag name followed by the coordinates of the point. The altitude coordinate, if left off, defaults to 0.

5. SAM sites - SAM sites define a SAM threat location. The SAM site contains a radar for tracking the pilot if the pilot is in range. As usual, the definition includes a tag name followed by the coordinates of the site. Note that no altitude is given due to the assumption that SAM sites are always on the ground.

SAM Sites:
sam_site1_tag : north_value (nmi) east_value (nmi)
sam_site2_tag : north_value (nmi) east_value (nmi)
sam_site3_tag : north_value (nmi) east_value (nmi)
.
.

6. AAA sites - AAA sites define a AAA threat location. The AAA site contains a radar for tracking the pilot if the pilot is in range. As usual, the definition includes a tag name followed by the coordinates of the site. Note that no altitude is given due to the assumption that AAA sites are always on the ground.

AAA Sites:
aaa_site1_tag : north_value (nmi) east_value (nmi)
aaa_site2_tag : north_value (nmi) east_value (nmi)
aaa_site3_tag : north_value (nmi) east_value (nmi)
.
.

7. Aircraft - Aircraft other than the pilot's aircraft can be specified. Aircraft have a radar system like the SAM and AAA sites. Aircraft are defined with an initial position and velocity. Aircraft fly in straight lines at constant velocity but their information can be updated by the simulation to simulate intelligent behavior.

Aircraft:
    ac1_tag :
        Position: north_value (nmi) east_value (nmi) altitude (ft)
        Velocity: vel_north (ft/min) vel_east (ft/min) vel_up (ft/min)

    ac2_tag :
        Position: north_value (nmi) east_value (nmi) altitude (ft)
    V     elocity: vel_north (ft/min) vel_east (ft/min) vel_up (ft/min)

    ac3_tag :
        Position: north_value (nmi) east_value (nmi) altitude (ft)
        Velocity: vel_north (ft/min) vel_east (ft/min) vel_up (ft/min)

        .
        .

8. Modes - User defined modes are useful when certain actions are to be limited to certain conditions specified by the researcher. As an example, use of the trigger button in a minimal information type of SA scenario can be enabled only during the declared mode MINIMAL and disabled during all other modes. Following is the syntax for user modes:

Modes: mode_name1, mode_name2, mode_name3, etc.

9. Bombs - The number of bombs which the pilot is allowed to carry is specified using the following syntax:

Bombs:
    Number: number

B. Triggers - Triggers are the mechanisms by which the simulation interacts with the pilot in ways specified by the researcher. Triggers respond to conditions in the simulation and execute preprogrammed operations. For a discussion of triggers plus a list of their components see the document "SAFTE Theory of Operation". Following is the syntax for declaring triggers. Note that triggers must follow all other object definitions in the scenario. This is in order to have reference to all tag names they might need:

Triggers:
    trigger_tag :
        Trigger type:
            (GLOBAL, LOCAL, MODAL)
        Count: (ALWAYS, number)
        Enabled: (YES, NO)
        Conditions: {...}
        Initial Positive Actions: {...}

Positive Actions: {...}
Initial Negative Actions: {...}
Negative Actions: {...}

.
.
.

Each trigger has three parameter fields and five code segments.

The three types of triggers are:
GLOBAL - the trigger is independent of any special condition for its evaluation and execution.

LOCAL - the trigger's evaluation and execution are dependent on where the pilot is. A local trigger is active within a given radius from a specified point. When using a LOCAL type the following additional syntax is needed (altitude is optional and defaults to 0):

Trigger type:
LOCAL:
Center: north_value (nmi) east_value (nmi) altitude (ft)
Radius: radius (ft)

MODAL - the trigger's evaluation and execution is dependent on the current mode of the simulation. See user defined modes above. Syntax for MODAL is:
Trigger type:
MODAL: mode_name

The Count parameter allows the trigger's operation to be limited to N activations, or have no limitations (keyword ALWAYS).

The Enabled field allows the trigger to be enabled or disabled at the beginning of the scenario. Disabled triggers can be enabled by other triggers or other mechanisms.

The five code segments are designed to contain C++ code using the object definitions within the simulation source code. Each segment can define an arbitrary sequence of instructions but must constitute a valid C function. The Conditions segment has the additional restriction that it must set the value of the processor status flag before it terminates. This allows the trigger to correctly evaluate the current conditions. The actual code goes between the {}s in the above syntax description.

## Creating the Scenario

Once the scenario file has been created the next step is to pre-compile the file into an objects database and a set of auto-generated code modules. The steps to follow are:

a. Have the scenario file in the SCENS sub-directory of the A directory on the

simulation machine.

b. From the A directory execute the batch file CS.BAT which will clear out any old scenario data.

c. Type "SIM 1 SCENS\FILENAME" and <enter>. This will create the object database and the auto-code modules. FILENAME is the name of the scenario file of interest.

d. Execute the batch file MAKW.BAT. This will recompile the simulation and include the new code.

The SIM program and the compiler will display warning or error messages if any syntactical errors are found. Refer to the set of .TXT file located in the SCENS directory for examples of many of the preceding syntax.

## Terrain Generator

This tool was designed to provide a graphical interface for constructing the terrain of the "world" in which the pilot flies. In addition to creating terrain the terrain generator allows the following operations: 1) importing of 3D objects into the database, 2) auto-shading, and 3) support for day/night and weather conditions.

At this point it should be noted that many of the terrain generator features have been created though a process of experimentation. Because of this several functions of the generator only work partially or not at all. The following procedures guide will help direct a potential user through this disjoint environment.

## Viewing Terrain

One of the most useful (and functional) feature of the generator is viewing the existing terrain. For the researcher who wishes to modify existing scenarios or create new ones, the terrain viewing feature allows the researcher to pinpoint locations on the map which can subsequently be entered into the scenario file as user points, way points, or SAM site or AAA site locations.

The first step in viewing is to read the terrain database into memory. Type "VIS" and <enter> to make sure that the current directory is the C:\VIS directory. Make sure that the latest version of the terrain database (name: TERRAIN.DAT) resides in this directory. Start the viewer by typing "EX" and <enter>. When the program starts a set of rectangular areas will be visible along with the mouse cursor in the upper left portion of the screen. Move the cursor over the R symbol at the lower right of the screen and single click with the mouse. In a few seconds the middle area of the screen will fill with the images of the terrain and object elements.

Moving the cursor over the picture will cause numbers in the lower left portion of the screen to change. These numbers are the East and North coordinates of the areas over which the mouse lies.

Move the cursor over the yellow down arrow at the lower right of the screen and single click again. Moving the cursor over the terrain map now results in a box being drawn over the same quadrant of the map that the cursor lies. Clicking on the map causes the generator to zoom into the chosen quadrant. At the lower left of the screen to the left of the mouse coordinates is a field named "level". This value indicates how many levels down the viewer currently is in the map.

Each level is exactly one half of the dimensions of the upper level. Clicking on the yellow up-arrow reverses the view. There are currently 12 levels supported for viewing.

## Creating and Deleting Objects

Objects in the terrain editor are created one facet (or face) at a time and laid down like sheets one on top of another. This means that objects like mountains can be constructed and placed on top of plains, but a topologically more complex object like a ball cannot be. An object can be constructed as one or more joined facets or as a more complex arrangement of groups of joined and disjoint facets. **Note:** only convex polygonal objects can be specified. Groups of objects can be formed to create more complex shapes.

When creating objects the color of the object and the 3D position of each vertex are specified. To begin constructing a simple object (i.e., one set of joined facets) click with the left mouse button on the "C" symbol at the lower right portion of the screen. A window will appear showing a selection of colors to choose from. Click on a color from the palette of colors shown. If the selected color needs to be modified, hold down the left button with the cursor over the RGB bars and slide each bar up or down to change the components of the color to create the desired shade. When finished, click the left mouse button on the red square at the lower left of the window to close it.

Having selected the object's color move the cursor to the point on the map where the first vertex of the object will be. Click once over the position with the left button and another window will appear allowing the altitude of the point to be specified. Move the altitude bar up or down by dragging the cursor up or down with the left button pressed over the bar area. For fine adjustments use the blue up and down arrows.

Once the altitude of the first point is chosen three options are available. If the altitude of each vertex needs to be specified independently click on the red box in the altitude window. Each time a new vertex point is picked the altitude window will appear allowing the altitude of the point to be selected. If the altitude of the entire object is to be the same as the first point click on the green button after selecting the first point's altitude. From this point until the object definition is finished the altitude box will not appear again and the altitude of each new point will be automatically assigned the altitude of the first point. This option is useful for quickly creating flat pieces of terrain.

If the position of a vertex is desired to coincide with the position of the vertex of another object then the yellow key is used. To use this option the cursor needs to be placed over the other vertex before the left button is pressed. When the yellow key is selected the generator will recall the coordinates of the selected vertex and assign these values to the new vertex. This option is useful for aligning different objects to create a mosaic.

To finish the object's definition press the right button after the last vertex has been entered. The generator will automatically close the polygon so defining an extra point is not necessary.

To combine groups of facets into more complex objects precede the above steps by clicking the "O" symbol at the lower right of the screen. Now an arbitrary number of groups of facets can be created with the above steps and assigned to one object. Close the new object's definition by clicking again on the "O" symbol.

To delete an object click on the "D" symbol at the lower right corner of the screen then click on the object to be deleted.

## Copying and Moving Objects

To move an object click on the "M" symbol at the lower right of the screen, click on the object to be moved, then click on the map where the object is to be placed. The screen will be redrawn with the object in the new position.

To copy an object follow the above steps but select the "cp" symbol instead. The screen will be redrawn showing both the old and the new objects.

## Scaling and Rotation

To scale an object's size up or down press the "-" (minus) or the "+" (plus) key from the keyboard then click on the object. The scaling increment is currently set at 5% of the current dimensions of the object.

To rotate left or right press the "l" or "r" key on the keyboard and click on the object. The increment of rotation is 2° at present.

## Editing an Object

To edit the color or vertices of an object the "E" symbol is first selected. To change the position and/or altitude of a vertex position the cursor over the vertex and click on it with the left button. Move the cursor to the new position and click again. The altitude window will appear allowing the altitude of the point to be modified. Once the altitude is selected the screen will be redrawn showing the modified object.

To change the color of an object click within the bounds of the object away from any vertices. The color window will appear allowing a new color to be selected or the currently selected color to be modified.

## Importing 3D Objects

Additional terrain or full 3D objects can be imported into the database for use in the simulation. This feature makes use of a separate program called CONVERT.EXE. The steps to do this are:

1. Create an object in a text editor according to the format shown in diagram 1.
2. Using a text editor strip out all information in the TERRAIN.DAT except that which defines the set of base colors (located at the beginning of the file) and that which defines the objects (located at the end of the file).
3. Insert the new object's definition in the file and save the information to a new file.
4. Execute "CONVERT FILE_IN FILE_OUT" where FILE_IN is the file just created and FILE_OUT is the new terrain file.
5. Replace TERRAIN.DAT with FILE_OUT.

Shading

To auto-shade the objects in the database for day/night and weather conditions (clear/cloudy) hit the s key on the keyboard. The program will indicate when shading is complete.

Saving the Data

To update the database click on the "S" symbol at the lower right corner of the screen. The database is now ready to be copied to the DATA sub-directory of the graphics machine and executed.

# APPENDIX 4

## INSTRUCTIONS FOR THE SAFTE SIMULATOR CONTROLS

Keyboard Switches

    l - landing gear toggle
    w - toggle waypoints
    t - toggle between chaff and flares
    r - reset max G counter and the flight director system

    keyboard switches must be in lower case to work correctly

Joystick Switches

    Red button under thumb at top - weapons release button

    Small black hat button under weapons release button - up/down for yes/no answers to SA questions

    Red trigger button on front - minimal information release button

    Red paddle button on front bottom - chaff/flare release

Throttle Switches

    Top white three way switch - mode switch:
        Near - Air-to-Ground
        Middle - NAV
        Far - Air-to-Air

    Two position white switch under mode switch - speed brake:
        Near - incremental extension (hold for maximum)
        Far - one shot automatic retraction

    Cursor under thumb - Air-to-Air radar target selector cursor
    Cursor button - select target

# APPENDIX 5

## SAFTE USER'S MANUAL

The SAFTE system is designed to provide researchers with an open-ended tool for collecting data on a range of situational awareness (SA) measures within the context of a real life task -- flying an airplane. The SAFTE system, as delivered, comes with a medium-to-high fidelity model of an F-16 aircraft, a simulated world database to fly around in, and a set of 83 prepared scenarios with embedded SA measures. The system also includes tools capable of both editing the current graphics database and scenarios, and creating new ones.

This Appendix is written to assist users in setting up the SAFTE system, executing existing scenarios and converting collected data into a useful format for analysis. For a detailed description of the operating principles of the SAFTE system, or of the scenario and terrain editing tools, refer to Appendices 1 through 4 of this report.

Overview

The SAFTE system is physically comprised of two Pentium computers connected via their parallel ports with a custom supplied cable. In this system, one machine is the simulation computer and the other is the graphics computer. Inputs from the controls run to the simulation machine and information is transmitted to the graphics machine through the parallel interface.

In addition, the SAFTE system comes equipped with a full set of control input devices: a flight stick (ThrustMaster FLCS), a throttle (ThrustMaster TQS) and rudders (ThrustMaster RCS). These devices are fitted with HOTAS (Hands On Throttle and Stick) controls which allow commands to be executed without having to remove ones hands from the keyboard. It is recommended that the manufacturer's documentation be reviewed prior to use in order to gain an understanding of the placement and operation of each of the controls used by the system. Note that SAFTE only uses a portion of the switches available on the controls, so a complete familiarization is not needed.

The execution of scenarios can be done in one of two ways: individually or as a programmed sequence. Auto-sequencing (discussed later) allows the researcher to step a subject through a custom set of scenarios without the subject having to remember each scenario. Whichever way is chosen, a uniquely named data file is generated for each scenario.

Setting Up the Equipment

The physical layout of the system consists of two computers. The fastest machine hosts the graphics software and the slower machine hosts the simulation software, as well as being equipped with the ThrustMaster game card. (See the "SAFTE User's Manual" -- Appendix 5, for detailed specifications concerning hardware requirements.)

Begin configuration of the system by setting the computers closely together and parallel to each other. Position the monitors near the computers, leaving enough space for the flight stick, throttle, and the Inteva keyboard. Remember to position the equipment so that the graphics monitor, the keyboard, and the controls are in a comfortable arrangement. Set the rudders on the floor directly underneath the other controls.

After physically positioning all the equipment, start assembling the system by hooking power cables to the computers and monitors and connecting the two computers together by attaching the supplied parallel cable to each computer's parallel port. Connect the Dell's keyboard to the top P2 connector on the back of the machine and connect the standard PC connector from the flight stick to the keyboard input of the Inteva. The Inteva's keyboard will be the primary keyboard input so the Dell's keyboard may be placed to one side.

Next, connect the "D" connector of the throttle's cable to the right hand side game port of the Inteva (as seen from the back), then use the correct gender connector on the rudder cable to connect the rudders to the back of the throttle. The "D" connector cable coming from the flight stick can now be connected to the other end of the rudder cable. Connect the Inteva's keyboard to the keyboard input of the flight stick. At this point all the hardware has been connected and the system can now be powered up. If computers different than those supplied under this effort are being used, refer to the system software requirements in the "SAFTE Theory of Operation" section of this report to verify that all required software is present.

Turn on each computer and verify that both machines correctly power up. If the systems are configured properly the graphics machine should begin executing the graphics program automatically after power up. If not, refer to the 'Troubleshooting' section of this Appendix for debugging assistance.

At this point, if machines other than the supplied systems are being used, an additional step will need to be performed. Reboot each machine in turn and enter the setup menu at the start of boot. Locate the portion of the menu specifying which parallel port protocol should be used and verify that it is set to allow standard bi-directional transfer. The terminology of different computer manufacturers can be different, so some experimentation may be necessary. Again, see the section on troubleshooting if problems persist.

Verify that both machines are up and running and the simulation computer is at the DOS C:> prompt. If this is the first time this equipment has been set up, then on the simulation computer type "TMS" and <enter>. This will invoke the ThrustMaster utilities program, which will be used to program the ThrustMaster controls. Follow the instructions for downloading files, specifying the file SAFTE.B50 under the PROGRAMS sub-directory. Refer to the ThrustMaster documentation for information on the TMS program and its use.

After completing the controls programming, type "A" and <enter>. This will transfer operations to the simulation directory where the simulation will be run and data files generated.

Before running the simulation, the stick, throttle and rudders must be calibrated. To do this, two procedures must be followed: First, before the calibration routine is run, the S1 button on the upper right of the flight stick MUST be pressed. This is to enable the programming of the controls. Second, run the calibration program by typing "CAL" and <enter>. The SAFTE calibration program will come up with a graphical and numerical presentation of the state of the controls. Using the paddle button on the stick's bottom front, and the trigger button on the stick's front, step through the calibration of each control, remembering to fully deflect the roll, pitch, and rudders, and accurately position the throttle at each detent point. To end the calibration, type "X" and return.

Running The Scenarios

Once the controls have been programmed and calibrated, the system is ready to be used for data collection. If only a specific scenario is desired, then simply type "S" and <return>.

When the program begins, a message asking for the subject's ID number will appear. When the subject's number is entered, the program then asks for the number of the scenario to run. After the scenario number is entered, a message appears on the graphics screen with details of the scenario. The scenario will begin after a key is pressed. At the end of the scenario, the program will exit, having created a data file in the simulation directory (C:\A).

If an automated sequence of scenarios is desired the following procedure is used:

0. Insert a floppy disk into the A: drive. This disk should contain the auto-sequencing file. From the simulation directory type "MAKEDISK" and <return>. The MAKEDISK program will ask for the subject's number, then the number of scenarios to execute, then finally the number of each scenario in order.
1. Once the MAKEDISK program has created the auto-sequencing file (called SAFTE.DAT) on the disk the subject is ready to execute the sequence of scenarios.
2. To start the simulation, insert the disk into the A: drive and type "M" from the simulation directory and <enter>. The program will begin by asking for the subject's ID number. If the number matches that on the disk file, the next action of the program will be to display a message on the graphics screen with the details of the first scenario to be run. From this point on the program behaves the same as the single scenario case. When the scenario finishes running, the simulation will return to the subject ID query. The subject can continue and execute the next scenario or quit the program entirely and resume at a later date.

A few points should be mentioned about using the auto-sequencing feature.

1. Each subject's ID must be registered with the program beforehand by including it in the file IDS.DAT in the sub-directory of the simulation directory (C:\A\SAFTEDAT). This is a text file with each ID number listed in order.
2. If the subject's ID has been registered on each SAFTE system in use, the subject is free to use any system he or she chooses by simply inserting the floppy with the auto-sequencing disk in the floppy drive of the selected machine.
3. If the subject aborts out of a scenario by hitting the ESC key the program will allow the scenario to be run one more time. After this, the program will advance to the next scenario regardless of the outcome of the repeated scenario.

Control and Keyboard Inputs

Input to the simulation comes from two main sources: the controls and the keyboard. The control inputs can be further divided into analog inputs (roll, pitch, rudder, throttle) and discrete inputs (trigger, weapons release button, etc.). Following is a list of the discrete controls used. After the controls list is a list of the valid keyboard inputs. Refer to the ThrustMaster documentation for locations and further descriptions of each control:

Control Inputs

Weapons Release Button - Located at the top back of the flight stick. Press to launch bombs or missiles.
Trigger - Located at the front top of the flight stick. Hold in to clear the screen during minimum information mode.
Slider Switch - Black four position switch located just under the weapons release button on the flight stick. Answers SA probe questions: Up is yes, down is no.
Paddle Switch - Red paddle switch located at the bottom front of the flight stick. Used to dispense chaff or flares (two at a time).
S1 Button - Red button located at the top right of the flight stick. This button enables the control programming. It MUST be pressed at the beginning of each session on the system after power up.
Mode Switch - Three way white switch located on top of the throttle. When pulled toward the pilot it enables CCIP (air-to-ground) mode. NAV (navigation) mode is in the middle and AAM (air-to-air mode) is the position away from the pilot.
Speed Brake - Two position white switch located below the Mode switch and toward the pilot on the throttle. This switch, when pulled toward the pilot, deploys the speed brake, and when pushed away, retracts the speed brake. Deployment is proportional to the amount of time the switch is pulled whereas retraction is automatically full and complete.
Track Ball /Mouse Button- Track ball/cursor knob located under the thumb on the throttle. This control is for the air-to-air radar cursor used in designating targets. Placing the return inside the cursor bounds and clicking the white "mouse key" switch located near the cursor control will designate the selected target.

Keyboard Inputs
c    - Clears the graphics screen of any messages and returns to normal OTW (Out-The-Window) processing
l    - Toggles landing gears
t    - Toggles countermeasures between chaff and flares
w    - Selects the next way point
Esc  - Aborts out of a scenario or quits the program and returns to DOS

Note: The keyboard inputs MUST be in lower case to function properly.


Data Analysis

Whether scenarios are run individually or as sets, the result is the creation of a data file for each scenario containing a history of the pilot's activity and the state of the aircraft. Each data file has a unique name that identifies, among other things, the subject ID, the scenario number and the reason for terminating the scenario (crash, time out, landing, etc.). ***Diagram 2 of the appendix contains a definition of each portion of the file name.

Note that when auto-sequencing scenarios, the file names will all have unique names derived from data contained in the SAFTE.DAT file on disk. If scenarios are run individually there is a possibility of creating data files with identical names. The researcher is cautioned to review his or her procedures being used before commencing data collection in this mode.

The contents of the data files is comprised of a collection of different data types having different

recording frequencies. The following list describes the types of data and their rate of occurrence. Refer to the previous appendices for a complete description of these data records:

<u>Data File Data Types</u>
Aircraft Output Vector - The vector of information detailing the aircraft's position, velocity, attitude and other parameters is transmitted to the data file once per second.
Control Input Vector - The vector of information detailing the values of the roll, pitch, throttle, and rudders is transmitted to the data file five (5) times per second.
Keyboard/Control Character Input Record - A character from the keyboard or from the discrete controls gets logged to the data file when it is entered.
SA Record - Situational Awareness (SA) record of an activity of an SA nature. The possible activities are detailed in the appendix. SA records are logged to the data file as they occur.

The following information is for researchers who are performing data analysis using the SAFTE data format. Each data record is time stamped with the time at which the data record was created. The starting point of the time value is not the beginning of the scenario, but rather the start of the program. While the program is running, there is a "real" time counter that keeps track of hours, minutes, seconds and fractional seconds. This is the total elapsed time since the simulation started. A second counter, the "simulation" time counter, keeps track of the time the scenario has actually run. It does not count the "pauses" that occur during SA probes. Time stamping data with "real" time values allows for the timing of events which occur while the simulation is halted, such as when waiting for the pilot to respond to an SA probe message.

The data set chosen for logging purposes is not a complete record of every occurrence, but rather an essential set of data from which other values can be inferred. A simple but important example of this is determining the start and stop of "simulation" time. There exists an SA record which records the enabling and disabling of the simulation time counter ("1" means enabling, "0" means disabling). From the activity of this record (called SIM TIME) a current value of simulation time can be constructed.

Data Extraction

The data contained in the data file is in a binary (non-text) format. To convert the data to a text format suitable for reading or input into a spreadsheet, the program FILTER.EXE is provided. To convert a file use <chdir> to change to the simulation directory, then type "FILTER <data file name> <output file name>" and <enter>. For full length scenarios running 20 minutes or longer the output file size can be considerably greater than one (1) megabyte in size. Each line of the output file is in the format:

[Time Stamp] [Data Record Type] [Data]

Be aware that for some records the line length may be substantially more than 80 characters.

Troubleshooting

The following is a basic troubleshooting guide for common problems:

Problem: Nothing happens on the graphics side when the simulation is run.

Solution: Verify that the parallel port cable is securely connected between the two machines. If this does not solve the problem the parallel port protocol specified by each computer's setup program may not be the correct one. Some experimentation may needed to find the correct values.

Problem: The ThrustMaster controls do not seem to work.
Solution: Make sure the red S1 button on the flight stick has been pressed since power up (but see below).

Problem: The controls will not work even after pressing the S1 button, or only some controls function but not others.
Solution: If the S1 button has been pressed, quit the program and from the DOS command line try operating the controls. If no characters appear on the command line then those controls are possibly are defective, or the device itself is defective.

Problem: "Config file failure" or "file not found" messages appear.
Solution: Verify that the path statement is correct. The easiest way to do this is to make sure the AUTOEXEC.BAT and CONFIG.SYS files supplied with the system are being used. Reboot the computer to enable any changes to the AUTOEXEC or CONFIG files.
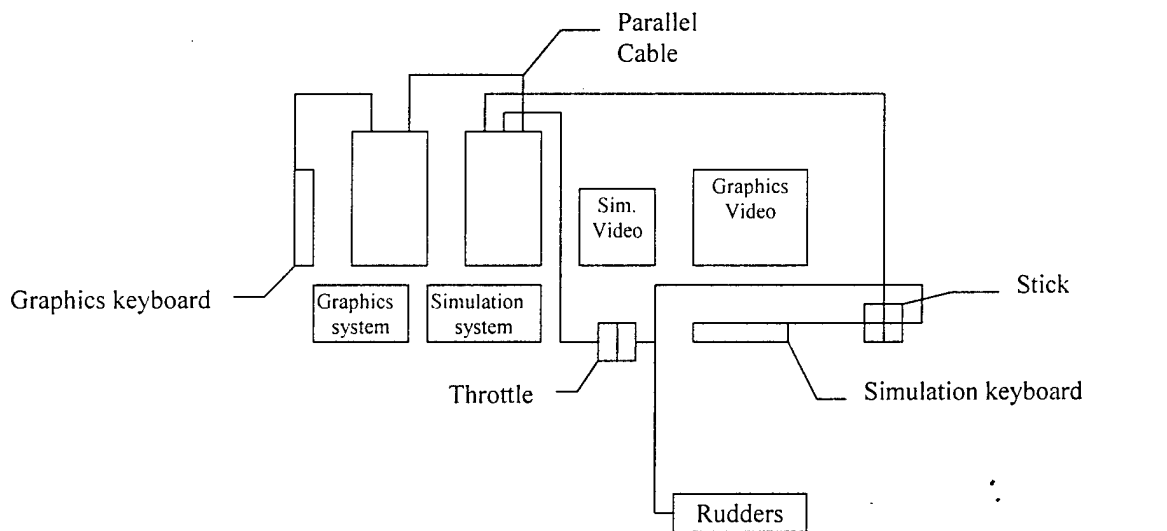
Diagram 5.1
Hardware Layout of SAFTE System

```
                    A A B B B C C D . E E E

A - Scenario number (0 - 99)
B - Cumulative number of runs (1 - 999)
C - Number of repeats for current scenario (0 - 99)
D - Ending scenario cause:
        1 - Computer crash
        2 - Successful ending
        3 - Time out
        4 - Crash landing
        5 - User abort
        6 - System operator abort
E - Subject number
```

Listing 5.1
SAFTE Data File Name Format

| Position | Name | Description |
|----------|------|-------------|
| 1 | AZN | // Normal accel. in gs |
| 2 | AYN | // Lateral accel. in gs |
| 3 | AXN | // Long. accel. in gs |
| 4 | QBAR | // Dynamic pressure in psf |
| 5 | MACH | // Mach number |
| 6 | VKT | // True airspeed |
| 7 | AOA | // AOA in deg. |
| 8 | BETA | // Slide Slip in deg. |
| 9 | PHID | // Pitch in deg. |
| 10 | THTAD | // Roll in deg. |
| 11 | PSID | // Heading in deg. |
| 12 | PD | // Roll rate in deg/sec |
| 13 | QD | // Pitch rate in deg/sec |
| 14 | RD | // Yaw rate in deg/sec |
| 15 | NORTH | // Position North in ft. |
| 16 | EAST | // Position East in ft. |
| 17 | ALT | // Position Down (Alt.) in ft. |
| 18 | QC | |
| 19 | QCOPS | |
| 20 | VNORTH | // Veloc. North in ft/sec. |
| 21 | VEAST | // Veloc. East in ft/sec. |
| 22 | VDOWN | // Veloc. Down (Alt.) in ft/sec. |
| 23 | HDOT | // Sink rate in ft/min. |
| 24 | CPOW | // Commanded power. |
| 25 | VCAS | // Calibrated airspeed |

Listing 5.2
Aircraft Output Vector

| Position | Name | Description |
|---|---|---|
| 1 | ROLL | // -1.0 to 1.0 full deflection |
| 2 | PITCH | // -1.0 to 1.0 full deflection |
| 3 | RUDDER | // -1.0 to 1.0 full deflection |
| 4 | THROTTLE | // 0.0 to 1.0 full throttle (AB) |

Note: Actual values may fall outside stated ranges due to calibration inaccuracies.

Listing 5.3
Controls Input Vector

| Button | Code | Character |
|---|---|---|
| S1 | 65 | Push - "A" |
| | 66 | Release - "B" |
| Trigger | 49 | Push - "1" |
| | 48 | Release - "0" |
| Slider Up | 72 | Push - "H" |
| Slider Down | 73 | Push - "I" |
| Slider Return | 76 | Return - "L" |
| Weapons Rel. | 45 | Press - "-" |
| "Pinky" btn. | 51 | Press - "3" |
| "Pinky" btn. | 50 | Release - "2" |
| Paddle btn. | 46 | Press - "." |
| CCIP mode | 34 | Press - """ |
| NAV mode | 35 | Return - "#" |
| ATA mode | 36 | Press - "$" |
| Speed Brake Ex. | 37 | Press - "%" |
| | 38 | Return - "&" |
| Speed Brake Rt. | 39 | Press - "'" |
| ATA Designate | 40 | Press - "(" |
| ATA Cursor, R | 41 | Press - ")" |
| ATA Cursor, L | 42 | Press - "*" |
| ATA Cursor, D | 43 | Press - "+" |
| ATA Cursor, U | 44 | Press - "," |
| Landing Gears | 108 | keyboard "l" |
| Counter Meas. | 116 | keyboard "t" |
| Way Points | 119 | keyboard "w" |

Note: This is an abbreviated listing. Please refer to the SAFTE.B50 file for complete information.

Listing 5.4
Control Character Codes

| Value | Name | Description |
|-------|------|-------------|
| 0 | SIM_MESSAGE | Display message |
| 1 | SIM_TGT_DESIG | Designate target |
| 2 | SIM_UNUSUAL_ATT | Do unusual attitude |
| 3 | SIM_TRIGGER_ACTV | Simulation trigger activation |
| 4 | SIM_TIME | Start/stop of simulation time |
| 5 | SIM_ATA_RADAR_TTA | TTA of designated target |
| 6 | SIM_RWR_RADAR | New guy RWR indication |
| 7 | SIM_CUR_WP | Selected way point value |

Listing 5.5
Recorded SA Activities

# APPENDIX 6

## TRAINING SCENARIOS PROGRAMMED IN SAFTE

Training scenarios

SUBJECT INSTRUCTIONS CHECKLIST FOR THE SABER PROJECT

PRE-TRAINING

Before the first hour of training, the subject will have been given copies of the "GENERAL TRAINING INSTRUCTIONS FOR AIR-TO-GROUND ATTACK MISSIONS" and the "GENERAL TRAINING INSTRUCTIONS FOR COMBAT AIR PATRIOL (CAP) MISSIONS". It is expected that they will have read through these prior to reporting for the first hour of training.

HOUR 1 FOR EACH SUBJECT (TOTAL TIME EST. = 48 minutes)

INTRODUCTION TO THE PROJECT  (10 minutes)

> Give a general introduction to the goals and background of the project
> AF SBIR - expected to be used in AF training and selection
> Constructed desk-top flight simulator with embedded SA measures
> Highest quality aerodynamics available on PC
> Current status - still a "prototype" - we expect some systems problems
> SABER project - determine basic learning curves for different experience levels on different maneuvers
> Performance expected - DO YOUR BEST - not expected to be "fighter pilots". Some missions may prove too difficult - this is OK.
> No scoring will be reported to UND - absolute privacy of data
> Finish all assigned missions. If systems failure occurs, re-initiate scenario.
> There will be 10 hours of "specific" training, followed by 10 hours of performance on "scenarios", or assigned missions.
> The activities covered in the "specific" training will all be required in the scenarios
> Any questions?

ORIENTATION TO THE SIMULATOR (20 minutes)

> (General Instructions)
> The learning goal here will be to give you a general familiarization with the simulator.
> The basic flight instruments will be explained, and you will get a chance to see the simulator being flown by the instructor.

INITIAL PRACTICE SESSION  (30 minutes)

> This will be a general session in which you are to try to "get the feel" of the aircraft.
> Practice will be in 2 minute segments in which you should simply go to an altitude of 5000 MSL, make several turns, and practice control of the aircraft.

<u>HOUR 2 FOR EACH SUBJECT  (TOTAL TIME EST. = 55 minutes)</u>

TAKE-OFF TRAINING (24 minutes)

TRAINING SCENARIO 1 - Daylight, CAVU conditions.
From dead stop, subject will initiate AB take-off.  Runway heading is 360.
Climb will be at 350 KCAS to 1,000 MSL.  Raise landing gear when safely
airborne.  Select MIL power at 250 KCAS.  Turn to heading 270 at 1,000 MSL
and continue MIL power climb to 5,000 MSL.  Terminate at 2 min. into exercise.
1 min rest.  <u>Repeat twice.</u>

TRAINING SCENARIO 2 - Daylight, low vis, low ceiling.

From dead stop, subject will initiate AB take-off.  Runway heading is 360.
Climb will be at 350 KCAS to 1,000 MSL.  Raise landing gear when safely
airborne.  Select MIL power at 250 KCAS.  Turn to heading 270 at 1,000 MSL
and continue MIL power climb to 5,000 MSL.  Terminate at 2 min. into exercise.
1 min. rest. <u>Repeat twice.</u>

REPEAT SCENARIOS 1 AND 2 (TWICE EACH)

NAVIGATION PRACTICE (25 minutes)

Instruction on instruments and mission - 15 minutes

The learning goal here will be to assure that you understand the navigation instruments,
and that you can maneuver the aircraft from one point to another with changes in
altitude.
During this hour, you will do one simple navigation exercise, involving the waypoint
indicator.  Waypoints will have been pre-programmed, and you are simply to fly to them.

SCENARIO #3 - NIGHT NAVIGATION

Aircraft will start at 350 KCAS/5,000 MSL, heading 270.  WP1 will be the dam.
Student will select WP1, and will turn to required heading, while executing 350 KCAS
MIL power climb to avoid mountains.  Level off at 20,000 MSL, maintaining 350
KCAS.  At WP1, student will select WP2 (Air Base #2), and turn to required heading.
At 10 nm prior to WP2, student will descend to be level at 500 AGL, and adjust speed to
arrive at WP2 at time 7 min.  Exercise will terminate when WP2 is reached, or after 8
min.  (Feedback - 2 minutes)


<u>HOUR 3 FOR EACH SUBJECT (TOTAL TIME EST. = 57 minutes)</u>

(Continuation of Navigation Training)

TRAINING SCENARIO 4 – Waypoint navigation with altitude change.

Aircraft will start at 350 KCAS/5,000 MSL, heading 270.  WP1 will be Factory #2.

Student will learn how WP information would be entered. Immediately upon scenario initiation, student will turn to required heading, while executing MIL power climb at 350 KCAS to level at 25,000 MSL. At WP1, student will select WP2 (bridge #2), and turn to required heading. Exercise will terminate when heading is achieved, or after 10 min.

## AIR TO AIR ATTACK TRAINING (Total time = 37 minutes)

The goal of this practice will be to provide intensive training on four specific air-to-air combat air patrol engagements in a night environment. Subjects will be given several practice sessions on each of the four air-to-air conditions. They should develop an "instinctive" response to each of the conditions, and respond as rapidly as possible whenever they recognize that a specific condition has occurred.

The following rules of engagement should be reviewed with the subject prior to entering into this phase of the training (10 minutes).

## ENGAGEMENT RULES:

When any target is detected within 40 nm West of WP1, assume to be hostile aircraft.

Bombers will be below 500 AGL and will maintain their original formation.

Fighters may be at any altitude, and may change their formation and/or altitude.

-------------------------------------------------------------------------------------------------

Determine which targets are bombers and which are fighters. In the absence of fighter activity or enemy radar lock-on, obtain a Primary Designated Target (PDT) on the nearest bomber and launch a Medium-Range Missile (MRM) at maximum range using heading and range guidance provided on radar and HUD. Attack each bomber in order of range, maintaining 450 KCAS/25,000 MSL during attacks. Continue to monitor all targets on radar until last MRM has achieved ACTIVE status. Then select MIL and perform a 5G level turn in the closest direction to WP1, maintaining 25,000 MSL.

If enemy fighters are detected, monitor their maneuvers. Adjust heading to keep all enemy fighters on the same side of the aircraft's nose. If enemy radar lock-on is detected inside lethal firing range, abort attack by selecting AB and performing a 5G level turn in the closest direction to WP1. Maintain 25,000 MSL and dispense 2 bundles of chaff when any hostile fighter with a radar lock passes through the beam (i.e., 90 deg off aircraft's nose/tail).

The following exercises will be repeated over the next 25 scenarios.

(Exercise 1 - all aircraft low - rear two targets maneuver after detection)
Student should abort attack and perform required maneuvers - 4 minutes + 1 minute rest

Initiate aircraft on outbound leg of CAP mission, heading 270, 350 KCAS/25,000 MSL. After 5 sec, radar will detect four enemy aircraft. All enemy will be at the same low altitude, with two in front and two 1 nm behind. Immediately, rear two targets separate into a "pincer maneuver" and radar lock is detected on RWR. Student should abort attack by selecting AB and performing 5G level turn in the direction closest to WP1. Maintain 25,000 MSL and dispense 2 bundles of chaff if any enemy fighter with a radar

lock passes through the beam (i.e., 90 deg off aircraft's nose or tail). Exercise will terminate with release of chaff, or after 4 minutes.

(Exercise 2 - all aircraft low - no maneuvering by any aircraft)
Student should attack each target in order of range - 4 minutes + 1 min rest

Initiate aircraft on outbound leg of CAP mission, heading 270, 350 KCAS/25,000 MSL. After 5 sec, radar will detect four enemy aircraft. All enemy will be at the same low altitude, with two in front and two 5 nm behind. No maneuvering or lock-on is detected. Student should obtain a Primary Designated Target (PDT) on the nearest bomber and launch a medium-range missile (MRM) at maximum range using heading and range guidance provided on radar and HUD. As long as there is no threatening movement. student should attack each target in order of range. Maintain 450 KCAS/25,000 MSL during attacks. Maintain radar contact on all targets until all MRMs are active, then select AB and perform a 5G turn toward WP1. Exercise will terminate upon achieving this heading, or after 4 min.

(Exercise 3 - two aircraft low and ahead, two high and behind - no lock on)
Student should attack front bombers as long as there is no lock on - 3 minutes + 1 min rest

Initiate aircraft on outbound leg of CAP mission, heading 270, 350 KCAS/25,000 MSL. After 5 sec, radar will detect four enemy aircraft. Two targets will be low, and 5 nm ahead of two high targets. No maneuvering or lock-on is detected. Student should obtain a Primary Designated Target (PDT) on the nearest bomber (low targets) and launch a medium-range missile (MRM) at maximum range using heading and range guidance provided on radar and HUD. Attack each bomber (low target) in order of range. Maintain 450 KCAS/25,000 MSL during attacks. As long as there is no threatening action by enemy, continue attacking targets in order of distance. Maintain radar contact with all targets until MRMs are active, then select AB and perform a 5G turn toward WP1.

(Exercise 4 - two aircraft high and in front, two low and behind - fighter lock on)
Student should perform max exit from area - 2 minutes + 1 min rest

Initiate aircraft on outbound leg of CAP mission, heading 270, 350 KCAS/25,000 MSL. After 5 sec, radar will detect four enemy aircraft. Two targets will be high, and 5 nm ahead of two low targets. Immediately, a "lock-on" warning is received, with no maneuvering by the enemy. Student should select AB and perform a 5G turn toward WP1. Student will maintain 25,000 MSL and dispense 2 bundles of chaff if any enemy fighter with a radar lock passes through the beam (i.e., 90 deg off aircraft's nose or tail). Exercise will terminate with release of chaff, or after 2 minutes.

SCENARIO 5: EXERCISE #1
SCENARIO 6: EXERCISE #2
SCENARIO 7: EXERCISE #3
SCENARIO 8: EXERCISE #1
SCENARIO 9: EXERCISE #4
SCENARIO 10: EXERCISE #1
SCENARIO 11: EXERCISE #4
SCENARIO 12: EXERCISE #3

SCENARIO 13: EXERCISE #4

HOUR FOUR FOR EACH SUBJECT (TOTAL TIME ESTIMATE = 58 minutes)

(Continuation of Air to Air scenarios) - 48 minutes

        SCENARIO 14: EXERCISE #3
        SCENARIO 15: EXERCISE #3
        SCENARIO 16: EXERCISE #2
        SCENARIO 17: EXERCISE #1
        SCENARIO 18: EXERCISE #2
        SCENARIO 19: EXERCISE #1
        SCENARIO 20: EXERCISE #2
        SCENARIO 21: EXERCISE #4
        SCENARIO 22: EXERCISE #3
        SCENARIO 23: EXERCISE #4
        SCENARIO 24: EXERCISE #2

"S-TURN INSTRUCTION - NO PRACTICE (10 minutes)

The learning objective here is to achieve skill with this aircraft simulation in performing basic flight maneuvers which are expected of Air Force pilots. The maneuvers required are taken from the basic Air Force UPT training syllabus.

(Video instruction describing the S-turns)

HOUR 5 FOR EACH SUBJECT (TOTAL TIME ESTIMATE = 60 minutes)

S-TURN PRACTICE

Each of the four S-turn maneuvers will be done three times (in succession). Each one will be initiated at a critical point where the pilot will have to perform the maneuver. The maneuver should not take much more than 4 minutes to perform. Therefore, the four S-turns, with two repetitions of each, and feedback to the subject, should not take more than 48 minutes.

        SCENARIOS #25, 26, 27)  S - TURN # 1 (repeat three times)
        SCENARIOS #28, 29, 30)  S - TURN # 2 (repeat three times)
        SCENARIOS #31, 32, 33)  S - TURN # 3 (repeat three times)
        SCENARIOS #34, 35, 36)  S - TURN # 4 (repeat three times)

LANDING INSTRUCTIONS - NO PRACTICE (12 minutes)

The learning goal here will be to give you the basic instructions on both visual and ILS landing.

(Video instructions - 12 minutes)

HOUR SIX FOR ALL SUBJECTS (TOTAL TIME ESTIMATE = 54 minutes)

LANDING PRACTICE

Visual Landing Practice  (24 minutes)

SCENARIO #37 Aircraft Visual approach, no crosswinds.

Aircraft will initiate at 350 KCAS/10,000 MSL, heading 090, at 10 nm South and 10 nm West of runway.  WP1 will be 10 nm North of runway.  Student will initiate a 300 KCAS descent to 2,000 MSL.  At WP1, student will turn directly to WPO (runway), maintaining 2,000 MSL and 300 KCAS until achieving a 3-deg glidepath to runway threshold.  Deploy speedbrakes, lower landing gear, and perform a straight-in approach and landing at 11 deg angle-of-attack (AOA).  Student will not exceed 15 deg AOA at touchdown.  Exercise will terminate with landing, or after 6 min. into the mission. Allow 2 min. for rest.

SCENARIO #38 REPEAT ABOVE SCENARIO (8 minutes)

SCENARIO #39 REPEAT ABOVE SCENARIO (8 minutes)

ILS Landing Practice (30 minutes)

(Practice of the ILS landing, using flight director, with some wind gusts - 6 minutes)

SCENARIO # 40 - Aircraft will initiate at 350 KCAS/10,000 MSL, heading 090, at 10 nm North and 10 nm West of runway.  WP1 will be 10 nm North of runway.  Student will intercept flight path and adjust heading as necessary to follow flight-director guidance to intercept the ILS course.  Maintain 2,000 MSL and 300 KCAS until intercepting ILS glideslope.  Deploy speedbrakes, lower landing gear, and perform an ILS flight-director approach at 11 deg AOA.

Upon reaching 200 AGL, perform a visual landing.  Do not exceed 15 deg AOA at touchdown.
Exercise will terminate with landing, or after 6 min. into the mission.  (2 min. rest)

SCENARIO # 40 - REPEAT ABOVE SCENARIO (8 minutes)

SCENARIO # 41 - REPEAT ABOVE SCENARIO (8 minutes)

SCENARIO # 42 - REPEAT ABOVE SCENARIO (8 minutes)

SCENARIO # 43 - REPEAT ABOVE SCENARIO (6 minutes)

HOUR SEVEN FOR EACH SUBJECT

CONTINUATION OF ILS APPROACH PRACTICE (TOTAL TIME ESTIMATE = 55 minutes)

The learning objective here is to achieve skill in the ILS approach without the aid of the flight director.

(Re-instruction in landing without flight director, and on mission -3 minutes)

SCENARIO #44 - Aircraft will initiate at 350 KCAS/10,000 MSL, heading 090, at 10 nm North and 10 nm West of runway. WP1 will be 10 nm North of runway. Student will intercept the ILS course with a maximum intercept angle of 45 deg. Maintain 2,000 MSL and 300 KCAS until intercepting ILS glideslope. Deploy speedbrakes, lower landing gear, and perform an ILS raw-data approach at 11 deg AOA. Upon reaching 200 AGL, perform a visual landing. Do not exceed 15 deg AOA at touchdown. Exercise will terminate with landing, or after 10 min. into the mission. (Rest 1 min.)

SCENARIO # 45 - REPEAT ABOVE SCENARIO (11 minutes)

SCENARIO # 46 - REPEAT ABOVE SCENARIO (11 minutes)

SCENARIO # 47 - REPEAT ABOVE SCENARIO (11 minutes)

SCENARIO # 48 - REPEAT ABOVE SCENARIO (11 minutes)

HOUR EIGHT FOR ALL SUBJECTS (TOTAL TIME ESTIMATE = 57 minutes)

AIR-TO-GROUND ATTACK PRACTICE (57 Minutes)

The learning objectives here, which will extend into the next hour of training, involve having the subject learn, practice, and become proficient at a specific air-to-ground attack maneuver. Practice will involve both systems variations and threat environments.

(Video Instruction on A-G pop-up attack - 15 minutes)

(Practice scenario under nominal and no-threat conditions - 5 minutes)

SCENARIO # 49 - Aircraft will initiate at 500 AGL/540 KCAS, 7 nm from target, which will be dam, and will be on a direct heading of 245 toward it. At IP (5nm) student will immediately select AB and perform a level, 5G right turn for 30 deg. Then student will pull up at 5G to 55-deg pitch angle and maintain this, wings-level, until reaching 9,800 AGL. Student will then immediately roll left (inverted) to place target locator line (TLL) vertical relative to the HUD, and pull down toward the target at 3G (keeping the TLL aligned vertically). Student will adjust throttle as necessary to achieve release speed of 500 KCAS.

When target is visually identified, student will position the Bomb Fall Line over it and track the target. Bombs will be released when the Pipper reaches the target. If the target is not identified visually, student should bomb the Target Designator Box (TDB).

Student will pull-out, wings level, by applying 5G within 2 secs following release, and will dispense 2 flares during pull-out. When nose reaches horizon, student will select Air-to-Air (AA) weapons mode and perform a level 5G left turn to designated heading, descending to 500 AGL and dispensing 2 flares during turn, maintaining full MIL power until 5 nm from target. At 5 nm from target, student will select NAV mode, and this will signal the end of the exercise. (4 min.). Rest 1 minute.

SCENARIO #50 - REPEAT ABOVE SCENARIO (5 minutes)

SCENARIO #51 - REPEAT ABOVE SCENARIO (5 minutes)

(Instruction on the above scenario if the target is not visually identified - bomb TDB - 2 minutes.)

SCENARIO #52 - REPEAT ABOVE SCENARIO. This scenario is the same as that above, but the target is not visually identified) (4 minutes plus 1 min. rest)

SCENARIO # 53 - REPEAT ABOVE SCENARIO - (no. 52)

SCENARIO # 54 - REPEAT ABOVE SCENARIO - (no. 52)

(Missile threat avoidance training)

The learning goal here focuses on missile avoidance during performance of the air-to-ground attack.

There will be three practice sessions in which SAM warning(s) will be given while the pilot is in the process of making an air-to-ground attack.

(Video instruction in missile avoidance and review of ground attack procedures - 10 minutes)


HOUR NINE FOR ALL SUBJECTS (TOTAL TIME ESTIMATE = 56 Minutes)

AIR-TO-GROUND ATTACK MISSIONS (CONT.)

Permit independent review of A-G mission with missile warnings. (4 minutes)

(Practice mission with missile warnings - 7 minutes)

SCENARIO # 55 - Aircraft will initiate at the river, at 500 AGL/540 KCAS. After 30 sec., SAM warning will be received on RWR, outside lethal range. Student should maneuver to AP, 5 nm from target, which will be Base #3 and will be on a direct heading of 270 toward it. Monitoring SAM warning, student will immediately select Mil Power and perform a level, 5G right turn for 30 deg. At this point, another SAM will be indicated within lethal range. Student will continue attack by pulling up at 5G to 55-deg pitch angle and maintaining this, wings-level, until reaching 9,800 AGL. Student will then immediately roll left (inverted) to place target locator line (TLL) vertical relative to the HUD, and pull down toward the target at 3G (keeping the TLL aligned vertically).

Student will adjust throttle to idle as nose passes through the horizon. Dispense two bundles of chaff during each turn.

When target is visually identified, student will position the Bomb Fall Line over it and track the target. Bombs will be released when the Pipper reaches the target. If the target is not identified visually, student should bomb the Target Designator Box.

Student will pull-out, wings level, by applying 5G within 2 secs following release, and will dispense 2 bundles of chaff during pull-out. When nose reaches horizon, student will select Mil-Power, perform a max-G descending turn in the nearest direction to place the threat 90 deg off aircraft's nose, while descending to 500 AGL. Student will dispense 2 bundles of chaff when this heading is reached, and perform another max-G turn directly to a heading of 090, dispensing another 2 bundles of chaff during this turn. Exercise will terminate at this point, or after 6 minutes. Rest 1 minute.

SCENARIO # 56 - REPEAT SCENARIO # 55 (7 minutes) - change location of the threat

SCENARIO # 57 - REPEAT SCENARIO # 55 (7 minutes) - change location of the threat

## SITUATION AWARENESS MEASURES TRAINING

General Training (15 minutes)

The general nature of the SA measures we are going to use should be explained. These should be linked to the overall purpose of the development - to develop on-line measures of SA in a flight simulator - for training and evaluation purposes.

We should cover the following types of SA measures:

The "blanking" technique - explain that the screen will go blank, and a statement/question will appear. The question will require a "true-false" or "yes-no" answer. Show the subject where to respond to these questions. There will be three categories of such questions. One will simply ask the subject whether something is or is not present in the environment (e.g., there is a SAM site to the right). The second will ask the subject to estimate or recall a distance (e.g., you are three miles from the target). The third will require the subject to estimate a future situation (e.g., you have to turn right in less than one minute).

Tell the subject that, except as noted below, the simulation will stop during these questions. The subject's "score" will be based on the speed of the response as well as its accuracy.

The spatial disorientation technique - explain that - occasionally - when the screen returns after one of the above questions, the aircraft may be in an unusual attitude. The subject's task is to recover from the unusual attitude as quickly as possible, and regain the assigned altitude, heading, and airspeed.

The minimal information technique - this will require the most explanation to the

subject. Explain that we are interested in how the person develops a "mental model" of the flight environment, and how much confidence the person has in that model (i.e., how confident that the model will predict event in the near future). Therefore, we want to subject to fly certain mission segments <u>with as little use of the displays as possible</u>. The displays (and out-the-window views) should be used whenever it is necessary to "update" the information the person believes is needed. However, this should be done <u>only when such information is absolutely required for safe flight and mission accomplishment</u>. In other words, we are asking the person to safely accomplish the mission with as little information as necessary!

We should explain that the final "score" will depend on how well the person flys, and also on how little they have to view the information. The best score will be to use the displays less than anyone else and fly the mission to near perfection. The worst score would be to crash or perform the mission badly (or not at all) because the person used the displays too little. Conversely, if the person flys very well, but doesn't turn the displays off at all, the score will be acceptable, but low. Assure the subject that we know this is not a realistic situation for the pilot, but that the information we can get from this kind of probe concerning the pilot's "mental model" makes the approach worthwhile.

Practice with the "blanking technique"

(Use training scenario #5 - VISUAL APPROACH LANDING - to demonstrate the three types of "blanking" questions.)

SCENARIO # 58 - The foundation for this will be TRAINING SCENARIO # 37 - Aircraft Visual approach, very mild crosswinds. Put the following SA questions in the scenario.

Aircraft will initiate at 350 KCAS/10,000 MSL, heading 090, at 10 nm South and 10 nm West of runway. WP1 will be 10 nm North of runway.

Fifteen seconds after scenario initiation:

"The runway is on your left" (ANS -- NO)

Student will deploy speedbrakes and initiate a 300 KCAS descent, to 2,000 MSL.

As aircraft passes 5,000 MSL:

"You are above 5,500 MSL" (ANS -- NO)

After achieving 2,000 MSL, but before waypoint #1:

"Your next action will be a left turn" (ANS -- NO)

At WP1, student will turn directly to WP0 (runway), lower landing gear and slow to 250 KCAS, maintaining 2000 MSL until achieving a 3-deg glidepath to runway threshold.

Deploy speedbrakes, and perform a straight-in approach and landing at 11 deg angle-of-attack (AOA). Student will not exceed 15 deg AOA at touchdown. Exercise will

terminate with landing, or after 6 min. into the mission.

(Video demonstration of unusual attitude recovery techniques. 10 minutes)


## HOUR 10 FOR EACH SUBJECT (TOTAL TIME ESTIMATE = 50 minutes)

## CONTINUATION OF SITUATION AWARENESS MEASURES TRAINING

The purpose of this hour of training is to give the subject experience and feedback on two of the SA measures - unusual attitude recovery and minimum information. The strategy in each case is to give a brief re-introduction to the techniques, and then to give a maximum amount of practice during the hour.

Unusual Attitude Recovery Training (36 minutes)

(For all of these practice sessions, we will use TRAINING SCENARIO # 4 as the basic vehicle.) Specifically, after the subject turns to WP # 1 and at various times during the climb to 25,000 MSL, we should momentarily blank the screen (1 to 2 seconds - or whatever time is required for us to re-set the aircraft's position), and then present the altered attitude. We estimate that each presentation should occupy no more than 6 minutes. We will use three basic unusual attitudes.

(THE UNUSUAL ATTITUDES ARE DEFINED IN APPENDIX 7)

SCENARIO # 59 - UNUSUAL ATTITUDE # 1
SCENARIO # 60 - UNUSUAL ATTITUDE # 2
SCENARIO # 61 - UNUSUAL ATTITUDE # 3
SCENARIO # 62 - UNUSUAL ATTITUDE # 2
SCENARIO # 63 - UNUSUAL ATTITUDE # 1
SCENARIO # 64 - UNUSUAL ATTITUDE # 3

Minimum Information Flying Training (25 minutes)

The goal here will be to give the subject a chance to fly several missions (which have previously been practiced) in the "minimum information" condition. During and after the practice, we should monitor the subject to see if he or she is really trying to fly well with minimum information. Watch out for the subject who tries to keep the display off all the time, and the one who never turns it off. We also want to discourage the subject who turns the display off repeatedly for less than a second. Emphasize that we want the person to constantly consider what it is that can be predicted reasonably in the next several seconds (or more).

The actual procedures we finally choose for this will depend on whether we can program the "normally on" - "normally off" - and/or "select individual displays" modes for this procedure. If so, we may have to revise the proposed schedule below. Assuming we have only the "normally on" mode, however, we can use the following schedule.

SCENARIO # 65 - NIGHT NAVIGATION. For this, use TRAINING SCENARIO # 3. (7 minutes).

103

SCENARIO # 66 - VISUAL APPROACH LANDING.  For this, use TRAINING
SCENARIO # 37. (6 minutes)

SCENARIO # 67.  AIR TO GROUND POP UP ATTACK.  For this, use TRAINING
SCENARIO # 49.  (4 minutes)

# APPENDIX 7

## MISSION SCENARIOS (AFTER TRAINING) PROGRAMMED IN SAFTE

SCENARIO 1: AIR-TO-GROUND ATTACK MISSION

Conditions:  daylight, clear, visibility unlimited (CAVU)

Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 1,000 MSL.  Raise landing gear when safely airborne and select MIL power at 250 KCAS.

(SA MEASURE A1: At 900 MSL, ask: YOU ARE NOW ABOVE 800 FEET. ANS -- TRUE)

Turn direct to Waypoint #1 (WP1) and continue 350 KCAS MIL power climb to level at 25,000 MSL.

(SA MEASURE B1: At 15,000 MSL, ask: YOU ARE TO LEVEL OFF AT 20,000 FT. ANS -- FALSE).

Turn direct to WP2 and maintain 350 KCAS/25,000 MSL.

(SA MEASURE B2: Immediately after WP2 has been entered, ask: YOUR NEXT ALTITUDE CHANGE WILL BE TO GO TO 600 MSL.  ANS -- FALSE

At WP2, turn direct to WP3 (Initial Point - IP) and descend to be level at 500 MSL 10 NM prior to reaching WP3.

(SA MEASURE A2: At 9 min. into the mission, ask: YOU ARE LESS THAN 8 MINUTES INTO THIS MISSION.  ANS -- FALSE)

Adjust speed as necessary to arrive at WP3 at time 10:00 (10 mins into mission).

(SA MEASURE B3: At 9:45 min. into the mission, ask: AFTER YOU REACH WP3, YOU SHOULD DESCEND TO 540 MSL.  ANS -- FALSE

At the IP select Air-Ground (AG) weapons mode, turn directly to WP4 (Target), and accelerate to 540 KCAS while maintaining 500 MSL.

(SA MEASURE A3: At 5 NM from the target, ask: YOU SHOULD SELECT AB NOW!  ANS -- FALSE

At 5 NM from Target (WP4), also Action Point (AP), select MIL-POWER and perform a level, 5G right turn for 30 deg.  Immediately pull up at 5G to 55-deg pitch angle.

Maintain 55-deg pitch angle and wings-level attitude until reaching 9,800 MSL.

(SA MEASURE C1: During ascent (at any point) ask: ROLLING LEFT IS THE QUICKEST WAY TO BRING THE TARGET VERTICAL RELATIVE TO THE HUD.  ANS -- TRUE)

Immediately roll left (inverted) to place the Target Locator Line (TLL) vertical relative to the HUD and pull down toward the target at 3G, keeping the TLL aligned vertically.

> (SA MEASURE B4: Immediately after subject begins the pull-down maneuver, ask: YOUR FINAL RELEASE ALTITUDE SHOULD BE 10,000 MSL. ANS -- FALSE)

Pull power to idle as the nose comes through the horizon.

When the Target is visually identified, position the Bomb Fall Line over the Target and track the Target. Release the bombs (Pickle Button) when the Pipper reaches the Target. If the Target is not identified, bomb the Target Designator Box.

> (SA MEASURE B5: If the altitude goes below 7,800 MSL, ask: YOU SHOULD PICKLE AS SOON AS THE PIPPER REACHES THE TARGET. ANS -- FALSE) If altitude does not go below 7,800 MSL, skip this question.

Abort the attack if a release is not performed prior to reaching 8,000 MSL.

Pull-out wings level by applying 5G within 2 secs following release. Dispense 2 flares during pull-out. When nose reaches horizon, select Air-to-Air weapons mode and perform a descending 5G left turn to a heading of 090 (East) and descend to 500 MSL, dispensing 2 flares during turn. Select MIL-POWER when level after the pullout, and maintain full MIL-POWER until 5 NM from Target.

> (SA MEASURE A4: Immediately after aircraft has descended to 500 MSL (or approximate) ask: THERE ARE NO ACTIVE SAMS TRACKING YOU. ANS -- TRUE)

At 5 NM from Target select NAV mode, turn directly to WP5, and perform a MIL power climb at 350 KCAS to 25,000 MSL.

> (SA MEASURE B5: At 5 NM prior to WP 5, ask: YOUR NEXT TASK WILL BE TO TURN TO WP 6 AND MAINTAIN ALTITUDE. ANS -- FALSE)

At WP5 begin a 300 KCAS descent to 2,000 MSL and turn directly to WP6.

> (SA MEASURE A5: As aircraft passes through 10,000 MSL, ask: YOU ARE NOW BELOW 10,000 MSL. ANS -- TRUE)

At WP6 turn directly to WP0 (runway). Maintain 2,000 MSL and 300 KCAS until achieving a 3-deg glidepath to runway threshold, then deploy speedbrakes, lower landing gear, and perform a straight-in approach and landing at 11 deg angle-of-attack (AOA). Do not exceed 15 deg AOA at touchdown.

## SCENARIO 2: COMBAT AIR PATROL (CAP) MISSION

Conditions: night, clear, visibility unlimited (CAVU)

Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 1,000 MSL.

(SA MEASURE B6: During takeoff roll, ask: YOUR CLIMB AIRSPEED WILL BE 350 KCAS. ANS -- TRUE)

Raise landing gear when safely airborne and select MIL power at 250 KCAS.

Turn direct to Waypoint #1 (WP1) and continue 350 KCAS MIL power climb to level at 25,000 MSL.

(SA MEASURE A6: PRIOR TO WP #1, ask: YOU SHOULD HAVE ALREADY SELECTED AIR-TO-AIR MODE. ANS -- FALSE)

At WP1 select Air-to-Air (AA) weapons mode and turn to a heading of 270 (West) for outbound leg of CAP pattern.

(SA MEASURE B6: When aircraft is 5 NM from WP1, ask: YOU WILL MAKE A RIGHT TURN IN 3 NM. ANS -- FALSE)

When 10 NM from WP1, make a 3G level left turn to a heading of 090 (East), maintaining 350 KCAS/25,000 MSL for inbound leg of CAP pattern. When abeam WP1, make a 3G level left turn direct to WP1 and resume outbound leg of CAP pattern, maintaining 350 KCAS/25,000 MSL.

(SUBJECT WILL MAKE THREE OF THESE "RACETRACK" PATTERNS BEFORE ENEMY AIRCRAFT APPEAR)

Monitor radar at all times while in CAP.

(SA MEASURE A7: During an early portion of the SECOND "outbound" leg of the maneuver, ask: YOU ARE NOW ON AN OUTBOUND LEG OF THE CAP PATTERN. ANS -- TRUE)

(SA MEASURE D1: WHEN THE SCREEN RE-APPEARS AFTER THE LAST SA QUESTION, THE AIRCRAFT WILL BE IN "UNUSUAL ATTITUDE #1", AND THE SUBJECT WILL HAVE TO RECOVER FROM THIS UNUSUAL ATTITUDE.) THE FLIGHT WILL THEN CONTINUE ACCORDING TO PLAN.

When any target is detected West of WP1, assume to be hostile aircraft. Determine which targets are bombers and which are fighters (THIS IS SA MEASURE #5).

Four targets appear on the radar screen on the outbound leg. Two aircraft will be in front, and two behind at approximately 5nm.

Obtain a Primary Designated Target (PDT) on the <u>nearest</u> bomber and launch a Medium-Range Missile (MRM) at maximum range using heading and range guidance provided on radar and HUD.

(SA MEASURE A8: Within 5 seconds after the first launch of a MRM on a bomber, ask: THERE IS NO SAM SITE TARGETING YOU AT THIS TIME. ANS -- TRUE)

<u>Attack each target identified as a bomber in order of range.</u> Maintain 450 KCAS during attacks. Continue to monitor all targets on radar until last MRM has achieved ACTIVE status.

(SA MEASURE E1: SCHEMA RESPONSE.)

If at any point enemy radar lock-on is detected inside lethal firing range, abort attack by selecting AB and performing a 5G level turn in the closest direction toward WP1. Maintain 25,000 MSL and dispense 2 bundles of chaff when any hostile fighter with a radar lock passes through the beam (i.e., 90 deg off aircraft's nose/tail).

(SA MEASURE B7: When aircraft reaches 2 NM from WP1, ask: THERE ARE NO ACTIVE RADAR OR AIRCRAFT THREATS AT THIS TIME. ANS -- TRUE)

On reaching WP1 reduce throttle to idle and deploy speedbrakes, select NAV mode, and turn directly toward WP2.

(SA MEASURE B8: When speed reaches 375 KCAS, ask: YOUR DESCENT SPEED WILL BE 300 KCAS. ANS -- TRUE)

Maintain 25,000 MSL until speed is reduced to 300 KCAS, then descend at 300 KCAS. Level at 2,000 MSL/300 KCAS.

At WP2 turn directly to WP0 (runway). Maintain 2,000 MSL and 250 KCAS until achieving a 3-deg glidepath to runway threshold, then deploy speedbrakes, lower landing gear, and perform a straight-in approach and landing at 11 deg angle-of-attack (AOA). Do not exceed 15 deg AOA at touchdown.


SCENARIO 3: (30 minutes for scenario plus rest)

Mission: Low-Low-Low Air-to-Ground Attack

Conditions: Daylight clear, visibility unlimited (CAVU)

Scenario: Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 500 MSL.

(SA MEASURE B9: As soon as aircraft is airborne, ask: YOUR TARGET ALTITUDE IS 1000 MSL. ANS -- FALSE)

Raise landing gear when safely airborne and select MIL power at 250 KCAS.

Turn direct to Waypoint #1 (WP1), maintaining 500 MSL and 350 KCAS.

> (SA MEASURE A9: Shortly after speed reaches near 300 KCAS, ask: YOUR SPEED IS NOW BELOW 350 KCAS. ANS -- TRUE)

> THE NEXT EVENT IS AN UNUSUAL ATTITUDE. HOWEVER, WE HAVE TO BE SURE THAT THE AIRCRAFT HAS ENOUGH ALTITUDE TO RECOVER FROM THE UNUSUAL ATTITUDE.

> (SA MEASURE D2 - UPON RETURN OF THE SCREEN, THE AIRCRAFT SHOULD BE IN UNUSUAL ATTITUDE # 3)

At WP1 turn direct to WP2. Maintain 500 MSL and accelerate to 480 KCAS.

> (SA MEASURE B10: When aircraft reaches 2 NM before WP2, ask: AT WP2, YOU WILL BEGIN YOUR ATTACK ON THE TARGET. ANS -- FALSE)

At WP2, turn direct to WP3 (Initial Point - IP). Maintain 500 MSL and adjust speed as necessary to arrive at WP3 at time 10:00 (10 mins into mission).

> (SA MEASURE C2: At 9:15 minutes into the mission, ask: YOU SHOULD HAVE LESS THAN 1 MINUTE LEFT BEFORE ARRIVING AT WP3. ANS -- TRUE)

At IP select Air-Ground (AG) weapons mode, turn directly to WP4 (Target), and accelerate to 540 KCAS while maintaining 500 MSL.

> (SA MEASURE B11: When aircraft is 7 NM from WP4, ask: YOU ARE NOW 7 NM FROM THE TARGET. ANS -- TRUE)

At 5 NM from Target (WP4), also Action Point (AP), select MIL-POWER and perform a level, 5G right turn for 30 deg. Immediately pull up at 5G to 55-deg pitch angle.

Maintain 55-deg pitch angle and wings-level attitude until reaching 9,800 MSL. Immediately roll left (inverted) to place the Target Locator Line (TLL) vertical relative to the HUD and pull down toward the target at 3G, keeping the TLL aligned vertically. Reduce throttle to idle as nose passes through the horizon.

> (SA MEASURE A11: If the aircraft reaches 500 KCAS, immediately ask: YOU ARE NOW AT YOUR BOMB RELEASE SPEED. ANS -- TRUE)

When the Target is visually identified, position the Bomb Fall Line over the Target and track the Target. Release the bombs (Pickle Button) when the Pipper reaches the Target. If the Target is not identified, bomb the Target Designator Box.

> (SA MEASURE B12: Immediately after pickle, ask: YOUR NEXT ACTIONS ARE: 1) TO PULL OUT AT 5G, AND 2) SELECT AIR-TO-AIR WEAPONS MODE. ANS -- FALSE)

Abort the attack a release is not performed prior to reaching 8,000 MSL.

Pull-out wings level by applying 5G within 2 secs following release. Dispense 2 flares during pull-out. When nose reaches horizon, select Air-to-Air weapons mode and perform a descending 5G left turn to a heading of 090 (East) and descend to 500 MSL, dispensing 2 flares during turn. Select MIL-POWER when leveland maintain until 5 NM from Target.

(SA MEASURE A12: When aircraft is 4 NM from the target, ask: YOU ARE NOW 5 NM FROM THE TARGET. ANS -- FALSE)

At 5 NM from Target select NAV mode, turn directly to WP5, decelerate to 480 KCAS and maintain 500 MSL.

At WP5 slow to 300 KCAS, climb to 2,000 MSL, and turn directly to WP6.

(SA MEASURE B13: Soon after aircraft reaches 2,000 MSL, ask: AT WP 6, YOU WILL BEGIN A STRAIGHT-IN VISUAL APPROACH. ANS -- FALSE)

(SA MEASURE D3: WHEN SCREEN APPEARS, THE AIRCRAFT WILL BE IN UNUSUAL ATTITUDE #2)

At WP6 turn toward WP0 (runway), adjusting heading as necessary to follow flight-director guidance to intercept the ILS course.

(SA MEASURE C3: While the pilot is following the flight director, ask: THE FLIGHT DIRECTOR APPEARS TO BE GIVING FALSE INFORMATION. ANS -- FALSE)

Maintain 2,000 MSL and 250 KCAS until intercepting ILS glideslope. Deploy speedbrakes, lower landing gear, and perform an ILS flight-director approach at 11 deg AOA. Upon reaching 200 AGL, perform a visual landing. Do not exceed 15 deg AOA at touchdown.


SCENARIO 4: (30 minutes, including scenario and rest)

Mission: Night Air-to-Air Combat Air Patrol (CAP)

Conditions: night, clear, visibility unlimited (CAVU) for takeoff; low ceiling poor visibility for landing

Scenario: Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 1,000 MSL. Raise landing gear when safely airborne and select MIL power at 250 KCAS.

Turn direct to Waypoint #1 (WP1) and continue 350 KCAS MIL power climb to level at 25,000 MSL.

(SA MEASURE B14: When aircraft passes through 10,000 feet, ask: YOU ARE

NOW MORE THAN HALFWAY THROUGH YOUR CLIMB TO ASSIGNED
ALTITUDE. ANS -- FALSE)

(SA MEASURE D5: WHEN THE SCREEN RETURNS, THE AIRCRAFT
SHOULD BE IN UNUSUAL ATTITUDE # 4)

At WP1 select Air-to-Air (AA) weapons mode and turn to a heading of 270 (West) for
outbound leg of CAP pattern.

(SA MEASURE A13: When aircraft is 9 NM from WP1, ask: YOU SHOULD
BEGIN YOUR LEFT TURN NOW. ANS -- FALSE)

When 10 NM from WP1, make a 3G level left turn to a heading of 090 (East),
maintaining 350 KCAS/25,000 MSL for inbound leg of CAP pattern.

When abeam WP1, make a 3G level left turn direct to WP1 and resume outbound leg of
CAP pattern, maintaining 350 KCAS/25,000 MSL.

THE PILOT WILL THEN DO FOUR OF THESE "RACETRACK" PATTERNS
BEFORE THE ENEMY PLANES APPEAR.

ON THE THIRD OUTBOUND LEG, JUST BEFORE THEY MAKE THEIR
TURN (ABOUT 9.5 NM FROM WP1) A SAM SITE RADAR WARNING
SHOULD OCCUR OUTSIDE OF LETHAL RANGE.

(SA MEASURE A14: After the radar warning has disappeared (on the inbound
leg of the third racetrack), ask: THERE ARE NO SAM SITES ACTIVE
WITHIN LETHAL RANGE. ANS -- TRUE)

(SA MEASURE D4: WHEN THE SCREEN RETURNS, THE AIRCRAFT
WILL BE IN UNUSUAL ATTITUDE #1.)

Monitor radar at all times while in CAP. When any target is detected West of WP1
within 40 NM of WP1, assume to be hostile aircraft. Determine which targets are
bombers and which are fighters.

(SA MEASURE E2: SCHEMA MEASURE)

ON THE FOURTH OUTBOUND LEG (WHEN THE AIRCRAFT IS 5 NM
FROM WP1) FOUR TARGETS WILL APPEAR ON THE RADAR. THE
FRONT TWO WILL BE HIGH, AND THE REAR TWO WILL BE LOW.
IMMEDIATELY, THE FRONT TWO WILL START TO MANEUVER AND A
LOCK-ON INSIDE LETHAL RANGE WILL OCCUR, SO THE REQUIRED
ACTION WILL BE TO TURN AND RUN.

If enemy fighters are detected, monitor their maneuvers. Adjust heading to keep all
enemy fighters on same side of aircraft's nose.

If enemy radar lock-on is detected inside lethal firing range, abort attack by selecting AB
and performing a 5G level turn in the closest direction toward WP1.

(SA MEASURE A14: When the aircraft is headed toward WP1, ask: THERE WAS NO NEED TO DISPENSE CHAFF DURING THE LAST TURN. ANS -- FALSE)

Maintain 25,000 MSL and dispense 2 bundles of chaff when any hostile fighter with a radar lock passes through the beam (i.e., 90 deg off aircraft's nose/tail).

AN ENEMY AIRCRAFT WILL CROSS THE BEAM

(SA MEASAURE A15: Fifteen seconds after speed brakes are deployed, ask: YOU SHOULD ALREADY HAVE SELECTED NAV MODE. ANS -- FALSE)

On reaching WP1 reduce throttle to idle and deploy speedbrakes, select NAV mode, and turn directly toward WP2.

Maintain 25,000 MSL until speed is reduced to 300 KCAS, then retract speedbrakes and descend at 300 KCAS. Level at 2,000 MSL/300 KCAS.

At WP2 turn toward WP0 (runway), lower landing gear and deploy speedbrakes, adjusting heading as necessary to follow flight-director guidance to intercept the ILS course. Maintain 2,000 MSL and 300 KCAS until intercepting ILS glideslope. Perform an ILS flight-director approach at 11 deg AOA.

ON THIS APPROACH, THE RUNWAY WILL NOT BECOME VISABLE TO THE PILOT BY 200 AGL.

If the runway is not acquired visually before the aircraft reaches 200 AGL, apply full MIL power, retract speedbrakes and climb straight ahead.

(SA MEASURE A16: When aircraft reaches 1000 MSL, ask: YOUR LANDING GEAR IS UP. ANS -- MUST BE COMPARED TO LANDING GEAR STATUS.)

When a positive rate of climb is achieved, raise landing gear. Continue climb at 300 KCAS to 2,000 MSL, then make a level right turn directly to WP2.

(SA MEASURE B15: At 2 NM from WP2, ask: AT WP2, YOU WILL MAKE A LEFT TURN. ANS -- TRUE)

AT THIS POINT, WE NEED TO ASSURE THAT VISABILITY IS ABOVE 200-300 AGL).

Reaching WP2, lower landing gear, slow to 250 knots and turn right to a heading of 045 until 5 NM from WP2, then make a level left turn to follow flight-director guidance to intercept the ILS course for another ILS approach.

SCENARIO 5: (30 minutes total for scenario and rest)
(SCENARIOS 9, 13, AND 18, WILL BE IDENTICAL TO THIS ONE - BUT THE SA

QUESTIONS WILL BE DIFFERENT).

THE FOLLOWING NUMBER OF SA MEASURES ARE ADDED INTO THE SCENARIO:

> A = 17 THROUGH 20
> B = 16 THROUGH 19
> C = 4 THROUGH 6
> D = 5 THROUGH 7
> E = NONE

Scenario "A" Description: This will be a "Vertical S-B" maneuver

Begin at 10,000 MSL, heading 180 (South) at 150 KCAS, 10 nm from WP1 (which is directly ahead). Gear and flaps down, speedbrakes deployed.

(SA MEASURE A17: At 5 nm from WP 1, ask: YOU ARE NOW LESS THAN 3 NM FROM WP1. ANS -- FALSE)

(SA MEASURE B16: At .5 nm from WP1, ask: YOUR NEXT MANEUVER WILL BE A DESCENDING LEFT TURN. ANS -- TRUE)

At WP 1, adjust power as necessary to establish a 1,000 ft/min rate of descent while maintaining 11 deg AOA and a left bank of about 30 deg.

Descend to 9,500 MSL, adjusting bank angle during descent as required to achieve a heading of 360 simultaneously with reaching 9,500 MSL.

Add power as necessary to establish a 1,000 ft/min climb rate while maintaining 11 deg AOA and the left bank required to achieve a heading of 180 simultaneously with regaining 10,000 MSL.

Level at 10,000 MSL, 11 deg AOA, heading 180.

Scenario "B" Description: This will be a "Vertical S-C" maneuver

Begin at 10,000 MSL, heading 180 (South) at 150 KCAS, 10 nm from WP1 (which is directly ahead). Gear and flaps down, speedbrakes deployed.

At WP 1, adjust power as necessary to establish a 1,000 ft/min rate of descent while maintaining 11 deg AOA and a left bank of about 30 deg. Descend to 9,500 MSL, adjusting bank angle during descent as required to achieve a heading of 360 simultaneously with reaching 9,500 MSL.

Add power as necessary to establish a 1,000 ft/min climb rate while maintaining 11 deg AOA and the left bank required to achieve a heading of 180 simultaneously with regaining 10,000 MSL.

On regaining 10,000 MSL and heading 180, repeat above maneuver to the right. Establish a 1,000 ft/min rate of descent while maintaining 11 deg AOA and a right bank of about 30 deg. Descend to 9,500 MSL, adjusting bank angle during descent as required

113

to achieve a heading of 360 simultaneously with reaching 9,500 MSL.

Add power as necessary to establish a 1,000 ft/min climb rate while maintaining 11 deg AOA and the right bank required to achieve a heading of 180 simultaneously with regaining 10,000 MSL.

Level at 10,000 MSL, 11 deg AOA, heading 180.


SCENARIO 6: (30 minutes total for scenario and rest)

Mission: Night Low-Altitude Air-to-Air Combat Air Patrol (CAP)

Conditions: night, clear, visibility unlimited (CAVU)

Scenario: Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 1,000 MSL. Raise landing gear when safely airborne and select MIL power at 250 KCAS.

        (SA MEASURE A21: As soon as the landing gear is retracted (if below 350 KCAS, ask: YOU ARE AT OR ABOVE 350 KCAS. ANS -- FALSE)

Turn direct to Waypoint #1 (WP1) and continue 350 KCAS MIL power climb to level at 25,000 MSL.

        (SA MEASURE B20: When aircraft passes through 10,000 feet, ask: YOU ARE NOW MORE THAN HALFWAY THROUGH YOUR CLIMB TO ASSIGNED ALTITUDE. ANS -- FALSE)

        (SA MEASURE B21: When aircraft is 11 NM from WP1, ask: YOU HAVE TO PERFORM AN ACTION IN 1 NM. ANS -- TRUE)

        (SA MEASURE D8: WHEN THE SCREEN RETURNS, THE AIRCRAFT WILL BE IN UNUSUAL ATTITUDE #2.)

10 NM prior to WP1 extend speedbrakes and descend at idle throttle to level at 1,000 MSL prior to reaching WP1. Retract speedbrakes and level at 1,000 MSL/350 KCAS.

        (SA MEASURE B22: When speedbrakes are extended OR idle throttle is reached,
ask: YOUR ASSIGNED ALTITUDE WILL NOT BE REACHED FOR THREE MINUTES. ANS -- FALSE)

        (ON THE ABOVE, THE ACTUAL DESCENT RATE IS CHECKED IN ORDER TO DETERMINE WHETHER THE ANSWER IS CORRECT OR NOT)

At WP1 select Air-to-Air (AA) weapons mode and turn to a heading of 270 (West) for outbound leg of CAP pattern.

        (SA MEASURE A22: When aircraft is 5 miles from WP1, ask: YOU ARE NOW

SIX MILES FROM WP1.  ANS -- FALSE)

When 10 NM from WP1, make a 3G level left turn to a heading of 090 (East),
maintaining 350 KCAS/1,000 MSL for inbound leg of CAP pattern.  When abeam WP1.
make a 3G level left turn direct to WP1 and resume outbound leg of CAP pattern,
maintaining 350 KCAS/1,000 MSL.

(SA MEASURE E3: SCHEMA MEASURE)

ON THIS SCENARIO, WE WILL ONLY HAVE THE STUDENT DO ONE
COMPLETE "RACETRACK".  ON THE SECOND OUTBOUND LEG, 1 NM
FROM WP1, THE FOUR TARGETS WILL APPEAR ON THE SCREEN.  ALL
WILL BE LOW (ALL BOMBERS).

Obtain a Primary Designated Target (PDT) on the nearest bomber and launch a Medium-
Range Missile (MRM) at maximum range using heading and range guidance provided on
radar and HUD.

(SA MEASURE A23: Immediately after the second MRM has been launched,
ask: YOUR SECOND MRM IS NOW "ACTIVE".  ANS -- TRUE

Attack each bomber in order of range.  Maintain 450 KCAS/1,000 MSL during attacks.

(SA MEASURE B23: Immediately after the third MRM has been launched, ask:
THE LAST TARGET IS PROBABLY A FIGHTER.  ANS -- FALSE)

Continue to monitor all targets on radar until last MRM has achieved ACTIVE status.
Then select MIL and perform a 5G level turn in the closest direction toward WP1,
maintaining 1,000 MSL.

(SA MEASURE A24: When the aircraft reaches 3G, ask: YOU ARE NOW
PULLING MORE THAN 4G.  ANS -- FALSE)

On reaching WP1 perform a MIL-power 350 KCAS climb to 25,000 MSL, select NAV
mode, and turn directly toward WP2.  Maintain 25,000 MSL until 10 NM from WP2,
then extend speedbrakes and descend at 300 KCAS to 2,000 MSL using idle throttle.
Retract speedbrakes and level at 2,000 MSL/300 KCAS.

(SA MEASURE B24: When aircraft reaches 10.5 NM from WP2, ask: YOUR
NEXT TARGETED ALTITUDE IS 2,000 MSL.  ANS -- TRUE)

At WP2 turn toward WP0 (runway), lower landing gear and deploy speedbrakes,
adjusting heading as necessary to intercept the ILS course with a maximum intercept
angle of 45 deg.  Maintain 2,000 MSL and 300 KCAS until intercepting ILS glideslope.
Perform an ILS raw-data approach at 11 deg AOA.  Upon reaching 200 AGL, perform a
visual landing.  Do not exceed 15 deg AOA at touchdown.

SCENARIO 7:  (30 minutes total for scenario and rest)

Conditions: Daylight attack and landing, low ceiling, poor visibility. <u>Ceiling at target is 2,500.</u>

Scenario: Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 1,000 MSL. Raise landing gear when safely airborne and select MIL power at 250 KCAS.

Turn direct to Waypoint #1 (WP1) and continue 350 KCAS MIL power climb to level at 25,000 MSL.

> (SA MEASURE A25: When aircraft reaches 21,000 MSL, ask: YOU ARE NOW ABOVE 20,500 MSL. ANS -- TRUE)

> (SA MEASURE D9: WHEN SCREEN RETURNS, AIRCRAFT WILL BE IN UNUSUAL ATTITUDE #3)

Turn direct to WP2 and maintain 350 KCAS/25,000 MSL.

> (SA MEASURE B25: When aircraft is three minutes from WP2, ask: IN JUST UNDER TWO MINUTES, YOU WILL BEGIN TO DESCEND. ANS -- FALSE)

At WP2, turn direct to WP3 (Initial Point - IP) and descend to be level at 500 MSL 10 NM prior to reaching WP3.

> (SA MEASURE C7: When aircraft is 3 min. from WP3, ask: YOU HAVE TRAVELED MORE THAN HALF THE DISTANCE BETWEEN WP2 AND WP3. ANS -- TRUE)

Adjust speed as necessary to arrive at WP3 at time 10:00 (10 mins into mission).

> (SA MEASURE B26: YOUR NEXT ACTION IS TO CLIMB. ANS -- FALSE)

At IP select Air-Ground (AG) weapons mode, turn directly to WP4 (Target), and accelerate to 540 KCAS while climbing to 1,500 MSL.

Continue to fly directly toward Target until visual identification is made. When the Target is visually identified, position the Bomb Fall Line over the Target and track the Target. Push over (bunt) into a shallow (5-deg) dive at release. Release the bombs (Pickle Button) when the Pipper reaches the Target.

If the Target is not identified, bomb the Target Designator Box.

> (SA MEASURE B27: When the aircraft passes 1,300 MSL, ask: YOU MUST ABORT THE ATTACK IF YOU HAVE NOT RELEASED THE BOMB BY 100 FEET LOWER THAN PRESENT ALTITUDE. ANS -- FALSE)

Abort the attack if dive angle (Flight Path Marker, FPM) exceeds 10 deg, or if a release is not performed prior to reaching 900 MSL.

Pull-out wings level by applying 5G within 2 secs following release.

(SA MEASURE B28: Immediately after release, ask: YOUR NEXT TURN IS TO THE EAST. ANS -- TRUE)

When nose reaches horizon, select full MIL power and Air-to-Air weapons mode, and perform a descending 5G left turn to a heading of 090 (East). Dispense 2 flares during turn. Descend to 500 MSL and maintain full MIL power until 5 NM from Target.

(SA MEASURE A26: When aircraft is 4.5 NM from target, ask: YOU ARE NOW 5 NM FROM THE TARGET. ANS -- FALSE)

At 5 NM from Target select NAV mode, turn directly to WP5, and perform a MIL power climb at 350 KCAS to 25,000 MSL.

(SA MEASURE A27: When aircraft passes 22,000 MSL, ask: YOU ARE NOW AT 22,000 MSL. ANS -- TRUE)

At WP5 begin a 300 KCAS descent to 2,000 MSL and turn directly to WP6.

(SA MEASURE C8: When aircraft passes 11,000 MSL, ask: YOU ARE MORE THAN HALFWAY TO YOUR NEW ALTITUDE. ANS -- TRUE)

At WP6 turn toward WP0 (runway), lower landing gear and deploy speedbrakes, adjusting heading as necessary to intercept the ILS course with a maximum intercept angle of 45 deg. Maintain 2,000 MSL and 300 KCAS until intercepting ILS glideslope. Perform an ILS raw-data approach at 11 deg AOA.

IN THIS SCENARIO, THE RUNWAY WILL NOT BE VISUALLY IDENTIFIED BY THE TIME THE AIRCRAFT REACHES 200 AGL.

If the runway is not acquired visually before the aircraft reaches 200 AGL, apply full MIL power, retract speedbrakes and climb straight ahead. When a positive rate of climb is achieved, raise landing gear.

(SA MEASURE A28: When aircraft passes 1,500 MSL, ask: YOU ARE NOW AT 1,200 MSL. ANS -- FALSE)

(SA MEASURE B29: Immediately after the last question is answered, ask: YOUR NEXT GOAL IS TO FLY TO WP5. ANS -- FALSE)

Continue climb at 300 KCAS to 2,000 MSL, then make a level right turn directly to WP6.

(AT THIS POINT, WE NEED TO ASSURE THAT VISABILITY IS ABOVE 200-300 AGL).

Reaching WP6, lower landing gear, slow to 250 KCAS, turn right to a heading of 045 until 5 NM from WP6, then make a level left turn to a heading of 225 deg to intercept the ILS course for another ILS approach.

SCENARIO 8: (30 minutes total for scenario and rest)

THIS WILL BE A MISSION IN WHICH WE USE THE "MINIMUM INFORMATION" TECHNIQUE. THE SUBJECT WILL BE INSTRUCTED THAT PORTIONS OF THE MISSION ARE TO BE FLOWN WITH ONLY THE DISPLAYS WHICH ARE ABSOLUTELY ESSENTIAL FOR SAFETY AND SUCCESSFUL MISSION COMPLETION. THESE SEGMENTS WILL BE INTRODUCED BY HAVING THE SCREEN GO "BLANK", AND THEN THE FOLLOWING MESSAGE WILL APPEAR FOR FIVE SECONDS: "UNTIL FURTHER NOTICE, YOU WILL HAVE TO CALL UP ANY INFORMATION YOU NEED BY CLICKING THE SCREEN." AT THE END OF THE MINUMUM INFORMATION SEGMENT, THE SCREEN GOES BLANK MOMENTARILY, AND A MESSAGE SAYS ("RETURN TO NORMAL FLYING PROCEDURES").

Mission: Night Air-to-Air Combat Air Patrol (CAP)

Conditions: night, clear, visibility unlimited (CAVU)

Scenario: Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 500 MSL. Raise landing gear when safely airborne and select MIL power at 250 KCAS.

(SA MEASURE F1: START MINIMUM INFORMATION SEGMENT)

Turn direct to Waypoint #1 (WP1); maintain 350 KCAS/500 MSL.

30 NM prior to WP1 begin a MIL power 350 KCAS climb to 25,000 MSL. Level at 25,000 MSL/350 KCAS.

At WP1 select Air-to-Air (AA) weapons mode.

(END MINIMUM INFORMATION SEGMENT AS SOON AS AA MODE IS SELECTED)

Turn to a heading of 270 (West) for outbound leg of CAP pattern.

(SA MEASURE C9: When aircraft is 7 NM from WP1, ask: YOU WILL MAKE A RIGHT TURN IN ABOUT 7 NM. ANS -- FALSE)

When 10 NM from WP1, make a 3G level left turn to a heading of 090 (East), maintaining 350 KCAS/25,000 MSL for inbound leg of CAP pattern.

When abeam WP1, make a 3G level left turn direct to WP1 and resume outbound leg of CAP pattern, maintaining 350 KCAS/25,000 MSL.

(SA MEASURE F2: START MINIMUM INFORMATION SEGMENT AS SOON AS AIRCRAFT REACHES WP1.)

WE WILL KEEP UP THE MINIMUM INFORMATION SEGMENT FOR TWO "REVOLUTIONS" OF THE RACETRACK. IT WILL END WHEN THE AIRCRAFT REACHES WP1 AFTER THE SECOND REVOLUTION.

Monitor radar as required while in CAP. When any target is detected West of WP1 within 40 NM of WP1, assume to be hostile aircraft. Determine which targets are bombers and which are fighters.

> ON THIS SCENARIO, THE FOUR TARGETS WILL APPEAR WHEN THE AIRCRAFT IS HALFWAY OUT ON THE OUTBOUND LEG. THE FRONT TWO TARGETS WILL BE BOMBERS (LOW) AND THE REAR TWO WILL BE FIGHTERS (BUT THEY WILL ALSO BE LOW). THE FIGHTERS WILL NOT MANEUVER UNTIL AFTER THE FRONT TWO BOMBERS HAVE BOTH BEEN ATTACKED. WE WILL ALSO INTRODUCE SAM WARNINGS, BUT THEY WILL BE OUTSIDE LETHAL RANGE.
>
> (SA MEASURE E4: SCHEMA MEASURE)

Obtain a Primary Designated Target (PDT) on the nearest bomber and launch a Medium-Range Missile (MRM) at maximum range using heading and range guidance provided on radar and HUD. Attack each bomber in order of range. Maintain 450 KCAS/25,000 MSL during attacks.

> AFTER THE FIRST MRM IS LAUNCHED, A SAM WARNING WILL APPEAR OUTSIDE OF LETHAL RANGE.

Continue to monitor all targets on radar until last MRM has achieved ACTIVE status.

> AFTER THE SECOND MRM IS LAUNCHED, THE TWO FIGHTERS WILL BEGIN TO MANEUVER, AND THEY WILL HAVE LOCK-ON INSIDE LETHAL RANGE.

If enemy fighters are detected, monitor their maneuvers. Adjust heading to keep all enemy fighters on same side of aircraft's nose. If enemy radar lock-on is detected inside lethal firing range, abort attack by selecting AB and performing a 5G level turn in the closest direction toward WP1. Maintain 25,000 MSL and dispense 2 bundles of chaff when any hostile fighter with a radar lock passes through the beam (i.e., 90 deg off aircraft's nose/tail).

> (SA MEASURE A29: As soon as (if) AB is selected, ask: THERE ARE NO ACTIVE SAM SITES IN THE AREA. ANS -- FALSE)
>
> (SA MEASURE D10: WHEN SCREEN RETURNS, THE AIRCRAFT WILL BE IN UNUSUAL ATTITUDE #4)

At WP1 turn direct to WP2.

> (SA MEASURE F3: START MINIMUM INFORMATION SEGMENT AS SOON AS WP2 IS ENTERED)

Extend speedbrakes and descend at idle power, 350 KCAS to 500 MSL. Retract speedbrakes and level at 500 MSL/350 KCAS.

5 NM prior to WP2 perform a MIL-power 350 KCAS climb to level at 2,000 MSL.

At WP2 turn toward WP0 (runway).

(END MINIMUM INFORMATION SEGMENT AS SOON WP2 IS
REACHED.)

Lower landing gear and deploy speedbrakes. Adjust heading as necessary to intercept
the ILS course with a maximum intercept angle of 45 deg. Maintain 2,000 MSL and 300
KCAS until intercepting ILS glideslope. Perform an ILS raw-data approach at 11 deg
AOA. Upon reaching 200 AGL, perform a visual landing. Do not exceed 15 deg AOA
at touchdown.


SCENARIO 9: (30 minutes total for scenario and rest)

THIS WILL BE THE SECOND S-TURN SCENARIO. WE WILL USE THE
FOLLOWING SA MEASURES IN THIS SCENARIO:

A = 30 THROUGH 34
B = 30 THROUGH 33
C = 10 THROUGH 12
D = 11 THROUGH 13
E = NONE
F = NONE


Scenario "A" Description: This will be a "Vertical S-B" maneuver

Begin at 10,000 MSL, heading 180 (South) at 150 KCAS, 10 nm from WP1 (which is
directly ahead). Gear and flaps down, speedbrakes deployed.

At WP 1, adjust power as necessary to establish a 1,000 ft/min rate of descent while
maintaining 11 deg AOA and a left bank of about 30 deg. Descend to 9,500 MSL,
adjusting bank angle during descent as required to achieve a heading of 360
simultaneously with reaching 9,500 MSL.

Add power as necessary to establish a 1,000 ft/min climb rate while maintaining 11 deg
AOA and the left bank required to achieve a heading of 180 simultaneously with
regaining 10,000 MSL.

Level at 10,000 MSL, 11 deg AOA, heading 180.


Scenario "B" Description: This will be a "Vertical S-C" maneuver

Begin at 10,000 MSL, heading 180 (South) at 150 KCAS, 10 nm from WP1 (which is
directly ahead). Gear and flaps down, speedbrakes deployed.

At WP 1, adjust power as necessary to establish a 1,000 ft/min rate of descent while
maintaining 11 deg AOA and a left bank of about 30 deg. Descend to 9,500 MSL,

adjusting bank angle during descent as required to achieve a heading of 360 simultaneously with reaching 9,500 MSL.

Add power as necessary to establish a 1,000 ft/min climb rate while maintaining 11 deg AOA and the left bank required to achieve a heading of 180 simultaneously with regaining 10,000 MSL.

On regaining 10,000 MSL and heading 180, repeat above maneuver to the right. Establish a 1,000 ft/min rate of descent while maintaining 11 deg AOA and a right bank of about 30 deg. Descend to 9,500 MSL, adjusting bank angle during descent as required to achieve a heading of 360 simultaneously with reaching 9,500 MSL.

Add power as necessary to establish a 1,000 ft/min climb rate while maintaining 11 deg AOA and the right bank required to achieve a heading of 180 simultaneously with regaining 10,000 MSL.

Level at 10,000 MSL, 11 deg AOA, heading 180.


SCENARIO 10

THIS WILL BE THE SECOND MISSION IN WHICH WE USE THE "MINIMUM INFORMATION" TECHNIQUE. THIS WILL BE AN AIR-TO-GROUND MISSION. THE SUBJECT WILL BE INSTRUCTED THAT PORTIONS OF THE MISSION ARE TO BE FLOWN WITH ONLY THE DISPLAYS WHICH ARE ABSOLUTELY ESSENTIAL FOR SAFETY AND SUCCESSFUL MISSION COMPLETION. THESE SEGMENTS WILL BE INTRODUCED BY HAVING THE SCREEN GO "BLANK", AND THEN THE FOLLOWING MESSAGE WILL APPEAR FOR FIVE SECONDS: " UNTIL FURTHER NOTICE, YOU WILL HAVE TO CALL UP ANY INFORMATION YOU NEED BY CLICKING THE SCREEN." AT THE END OF THE MINIMUM INFORMATION SEGMENT, THE SCREEN GOES BLANK MOMENTARILY, AND A MESSAGE SAYS ("RETURN TO NORMAL FLYING PROCEDURES").

Mission: Low-High-Low Air-to-Ground Attack

Conditions: Daylight attack and landing, low ceiling, poor visibility for landing, CAVU for takeoff and in target area

Scenario: Normal afterburner (AB) takeoff with a 350 KCAS climb on runway heading to 500 MSL. Raise landing gear when safely airborne and select MIL power at 250 KCAS.

> (SA MEASURE F4: START MINIMUM INFORMATION SEGMENT AS
> SOON AS THE LANDING GEAR ARE RETRACTED.)

Turn direct to Waypoint #1 (WP1), maintaining 500 MSL and 350 KCAS.

At WP1 turn direct to WP2 and perform a MIL-power climb at 350 KCAS to 25,000 MSL. Accelerate to 420 KCAS after reaching 25,000 MSL.

At WP2, turn direct to WP3 (Initial Point - IP) and descend to be level at 500 MSL 10

NM prior to reaching WP3. Adjust speed as necessary to arrive at WP3 at time 10:00 (10 mins into mission).

At IP select Air-Ground (AG) weapons mode, turn directly to WP4 (Target), and accelerate to 540 KCAS while maintaining 500 MSL.

(END MINIMUM INFORMATION SEGMENT AS SOON AS AG MODE IS SELECTED.)

At 5 NM from Target (WP4), also Action Point (AP), select MIL-POWER and perform a level, 5G right turn for 30 deg.

(SA MEASURE C13: When aircraft has turned 15 deg., ask: YOU ARE AT LEAST HALFWAY THROUGH YOUR REQUIRED TURN. ANS -- TRUE)

Immediately pull up at 5G to 55-deg pitch angle.

Maintain 55-deg pitch angle and wings-level attitude until reaching 9,800 MSL.

(SA MEASURE A35: When aircraft passes through 5,000 MSL, ask: YOU ARE NOW AT 6,000 MSL. ANS -- FALSE)

Immediately roll left (inverted) to place the Target Locator Line (TLL) vertical relative to the HUD and pull down toward the target at 3G, keeping the TLL aligned vertically. Select idle power as nose passes through horizon.

AS SOON AS THE POWER IS REDUCED TO IDLE IN THIS CONDITION, A SAM WARNING WITHIN LETHAL RANGE WILL BE GIVEN.

The student should proceed with the mission. When the Target is visually identified, position the Bomb Fall Line over the Target and track the Target. Release the bombs (Pickle Button) when the Pipper reaches the Target. If the Target is not identified, bomb the Target Designator Box.

Abort the attack if release is not performed prior to reaching 8,000 MSL.

Pull-out wings level by applying 5G within 2 secs following release. Dispense 2 flares during pull-out.

After dive recovery, perform a max-G turn in nearest direction to place threat 90 deg off aircraft's nose while descending to 500 AGL.

(SA MEASURE B34: As soon as a 2-G turn is detected, ask: YOU HAVE ALREADY DISPENSED FOUR BUNDLES OF CHAFF IN THIS MANEUVER. ANS -- FALSE)

Dispense 2 bundles of chaff during this turn, then perform a max-G turn directly to a heading of 090 (East), dispense 2 additional chaff bundles.

When nose reaches horizon, select Air-to-Air weapons mode and perform a level 5G left

turn to a heading of 090 (East) and descend to 500 MSL, dispensing 2 flares during turn.

(SA MEASURE B35: When the aircraft is 3 NM from the target, ask: YOU SHOULD HAVE CHANGED THE NAV MODE BY THIS TIME. ANS -- FALSE)

Maintain full MIL power until 5 NM from Target.

At 5 NM from Target select NAV mode, turn directly to WP5, decelerate to 480 KCAS and maintain 500 MSL.

At WP5 slow to 300 KCAS, climb to 2,000 MSL, and turn directly to WP6.

At WP6 turn toward WP0 (runway), lower landing gear and deploy speedbrakes, adjusting heading as necessary to follow flight-director guidance to intercept the ILS course. Maintain 2,000 MSL and 300 KCAS until intercepting ILS glideslope. Perform an ILS flight-director approach at 11 deg AOA.

(AT THIS POINT, WE NEED TO ASSURE THAT VISABILITY IS ABOVE 200-300 AGL).

When the runway is visually identified, perform a visual landing. Do not exceed 15 deg AOA at touchdown.

FOR SCENARIOS 11 TO 20, REPEAT THE ABOVE 10 IN A RANDOM ORDER.

# APPENDIX 8

## THE DATA GENERATOR FOR SAFTE

The raw data are broken down into twelve distinct types of events. Whenever any one of these events occurs, it is written as a single record. Detection of these events is based on measuring changes in the readings (which are sampled at varying rates for different types of data - ranging from 5/sec for user input values to 1/sec for aircraft state values.) Detection occurs when a threshold trip value is surpassed and ends when the event fails to exceed a threshold stop value. Written into the program is the ability to change the threshold levels for both the trip value and the stop value. The trip value sets the minimum value a variable must change to initiate a record. The stop value sets the maximum value a variable can change to end a record. For example, if the threshold values for an altitude change are: Trip = 75; Stop = 5, then once the aircraft has changed a total of 75 or more feet from the end of the last record, a new "event" will be initiated. This new event will end when the aircraft makes a change in altitude of 5 feet or less from one sample to the next. (The record will also end if the direction of movement changes.)

Table 1 below lists the meaning of the 14 columns contained in the data generator. This Table summarizes the contents of the summary generator. The output file is formatted for input into a spreadsheet or into another program. In other words, using this output, the researcher will be able to extract required information and carry out statistical analyses.

### TABLE 8.1

### CONTENTS OF THE DATA GENERATOR

| Column | TYPE OF DATA |
| --- | --- |

1 Record Type
    0 = Start/Stop
    1 = Speed change
    2 = Altitude change
    3 = Heading change
    4 = Throttle adjustment
    5 = Pitch deflection
    6 = Roll deflection
    7 = Rudder deflection
    8 = Straight & Level
    9 = Unusual attitude
    10 = User input (keypress)
    11 = SA measure

2 Time into scenario - Elapsed flying time
3 Duration for record types 1-9
        Raw time into scenario for record types 0, 10, & 11
4 Calibrated airspeed - at initiation of record
5 Altitude - at initiation of record
6 Heading - at initiation of record
7 Position North - at initiation of record

8 Position East - at initiation of record
9 Average Angle-Of-Attack (AOA) for record type 2 (Altitude changes)
   Average Gz pulled for record type 3 (Heading changes)
   Average Deflection value for records 5-7 (Flight stick and rudder)
   Heading deviation for record type 8 (Straight & Level)
10 Standard Deviation of AOA for record type 2 (Altitude changes)
   Standard Deviation of Gz pulled for record type 3 (Heading changes)
   Standard Deviation of Deflection value for records 5-7 (Flight stick and rudder)
   Altitude Deviation for record type 8 (Straight & Level)
11 Max Angle-Of-Attack (AOA) for record type 2 (Altitude changes)
   Max Gz pulled for record type 3 (Heading changes)
   Max Deflection value for records 5-7 (Flight stick and rudder)
12 Direction of change        1  =  Up/Right/Increase
                             -1  =  Down/Left/Decrease
13 Ending Speed for record types 1 & 4 (Speed/Throttle changes)
   Ending Altitude for record types 2 & 5 (Altitude/Pitch changes)
   Ending Heading for record types 3, 6 & 7 (Heading/Roll/Rudder changes)
   SA activity for record type 11
14 Speed change per second for record type 1
   Altitude change per second for record type 2
   Heading change per second for record type 3
   ASCII value of keypress for record type 10
   SA message for record type 11

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A portion of an actual summary output is shown in Table 8.2. The first record is the scenario start. (Time of start, 0.182. is the time of the first aircraft state record.) The generator then detected two rudder movements, first to the right then to the left. These caused the heading of the aircraft to change from .01° to 359.85° then from 359.78° to 359.97°. Then a speed change is detected (throttle motion not implemented at the time of writing) starting at 11.142 seconds into the scenario and lasting for 12.025 seconds. The speed started at 23.5 knots and ended at 261.64 knots. Another rudder movement to the right was detected, followed by an upward pitch deflection. At 17.142 seconds into the scenario a change in altitude was detected resulting in a climb for 6.025 seconds and an altitude change from 3.41' to 188.52'. This was accompanied by a pitch deflection during the same time period. The pitch deflection is down and it appears that the subject was trying to reduce the natural ascent rate accompanying lift-off. At 18.807 seconds into the scenario (43.667 seconds since this session began - raw time) SA message number 7301 was displayed resulting in a response by the subject (ASCII value 73 resulting from a 'Slider Down' on the flight stick) at raw time 46.649. It is possible to calculate the response time for the message to be 2.982 seconds. (The next record is a result of the 'return to normal position' of the slider switch on the flight stick and may be disregarded for our purposes.) The scenario time clock is paused while SA messages are displayed. Two more pitch deflections are then registered, one upward then one downward. A user input of ASCII value 108 (in our scenario this equates to raising of the landing gear - pressing keyboard 'L') occurred 23.241 seconds into the scenario when the aircraft was at an altitude of 188.52'. An SA message 7302 was then displayed at scenario time 25.072 seconds, with an unusual attitude (SA record with SA activity 2 and indicating unusual attitude 1) beginning at the same time.

## TABLE 8.2

### SAMPLE OF OUTPUT FROM THE DATA GENERATOR
#### (One Subject - One Segment of Flight)

COLUMN

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.182 | 0.000 | 2.59 | 9.89 | 0.01 | 188119.4 | 814786.0 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 1.00 |
| 7 | 0.182 | 4.800 | 2.59 | 9.89 | 0.01 | 188119.4 | 814786.0 | 0.14 | 0.03 | 0.17 | 1 | 359.85 | 0.00 |
| 7 | 5.542 | 3.600 | 2.59 | 14.99 | 359.78 | 188240.7 | 814786.0 | 0.17 | 0.01 | 0.18 | -1 | 359.97 | 0.00 |
| 1 | 11.142 | 12.025 | 2.59 | 23.50 | 0.30 | 188400.0 | 814786.0 | 0.00 | 0.00 | 0.00 | 1 | 261.64 | 20.94 |
| 7 | 11.942 | 2.240 | 2.59 | 23.50 | 0.30 | 188400.0 | 814786.0 | 0.13 | 0.01 | 0.14 | 1 | 359.46 | 0.00 |
| 5 | 16.182 | 0.800 | 2.70 | 125.34 | 358.64 | 188998.5 | 814782.3 | 0.12 | 0.01 | 0.13 | 1 | 2.70 | 0.00 |
| 2 | 17.142 | 6.025 | 3.41 | 146.32 | 358.95 | 189218.1 | 814779.3 | 3.02 | 7.63 | 14.27 | 1 | 188.52 | 30.86 |
| 5 | 17.382 | 3.385 | 3.41 | 146.32 | 358.95 | 189218.1 | 814779.3 | 0.61 | 0.21 | 0.92 | -1 | 132.43 | 0.00 |
| 11 | 18.807 | 43.667 | 22.10 | 162.86 | 359.01 | 189489.2 | 814774.4 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 7301.00 |
| 10 | 18.807 | 46.649 | 22.10 | 162.86 | 359.01 | 189489.2 | 814774.4 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 73.00 |
| 10 | 19.011 | 46.886 | 22.10 | 162.86 | 359.01 | 189489.2 | 814774.4 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 76.00 |
| 5 | 20.767 | 0.960 | 132.43 | 197.37 | 358.99 | 190072.1 | 814762.1 | 0.25 | 0.13 | 0.35 | 1 | 176.33 | 0.00 |
| 5 | 21.967 | 1.600 | 176.33 | 217.64 | 358.80 | 190433.9 | 814755.6 | 0.15 | 0.04 | 0.20 | -1 | 188.52 | 0.00 |
| 10 | 23.241 | 51.116 | 188.52 | 261.64 | 358.97 | 191244.0 | 814743.1 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 108.00 |
| 11 | 25.072 | 52.947 | 167.95 | 282.94 | 358.93 | 191685.3 | 814737.1 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 7302.00 |
| 11 | 25.072 | 52.947 | 113.01 | 319.07 | 292.19 | 192159.6 | 814729.3 | 0.00 | 0.00 | 0.00 | 0 | 2.00 | 1.00 |
| 10 | 25.072 | 55.067 | 113.01 | 319.07 | 292.19 | 192159.6 | 814729.3 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 73.00 |
| 9 | 25.072 | 16.906 | 2346.75 | 380.80 | 269.97 | 192859.2 | 805517.1 | 0.00 | 0.00 | 3.05 | 0 | 0.00 | 0.00 |
| 10 | 25.149 | 55.173 | 113.01 | 319.07 | 292.19 | 192159.6 | 814729.3 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 76.00 |
| 10 | 42.474 | 72.498 | 2346.75 | 380.80 | 269.97 | 192859.2 | 805517.1 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 119.00 |
| 11 | 42.474 | 72.498 | 2346.75 | 380.80 | 269.97 | 192859.2 | 805517.1 | 0.00 | 0.00 | 0.00 | 0 | 7.00 | 0.00 |
| 10 | 43.316 | 73.340 | 2273.16 | 384.23 | 270.00 | 192859.2 | 804826.8 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 119.00 |
| 11 | 43.316 | 73.340 | 2273.16 | 384.23 | 270.00 | 192859.2 | 804826.8 | 0.00 | 0.00 | 0.00 | 0 | 7.00 | 1.00 |
| 5 | 43.978 | 2.240 | 2201.22 | 387.42 | 270.01 | 192859.2 | 804185.4 | 0.11 | 0.03 | 0.13 | 1 | 2069.69 | 0.00 |
| 6 | 49.418 | 0.800 | 1991.80 | 397.33 | 270.00 | 192862.9 | 800746.5 | 0.24 | 0.16 | 0.37 | -1 | 269.84 | 0.00 |

The response from the subject (ASCII value 73 - 'Slider Down") to the SA message took 2.12 seconds. The unusual attitude record reports that it took 16.906 seconds for the subject to recover from the unusual attitude. The SA record showing the start of the unusual attitude reports the aircraft state values at initiation and the unusual attitude record shows the ending state values. An unusual attitude is considered to be over when the wings of the aircraft are level for two state readings. (The next record is another 'return-to-normal' record.) At scenario time 42.474 seconds the subject input a waypoint selection ('W' on the keyboard) and the next SA record reports WP0 selected (SA activity 7 and message 0.) A waypoint selection of WP1 follow. The sample portion ends with a detected upward pitch and left roll deflection.

## FLIGHT PERFORMANCE VALUES OBTAINED
## IN THE DEMONSTRATION PROJECT

## NORTH DAKOTA DEMONSTRATION ANALYSIS  -  Mean Performance By Experience Level and Attempt Number

| Means | | A01 | A02 | A03 | A04 | A05 | A06 | A07 | A08 | A09 | A10 | A11 | A12 | A13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FM01 | 0 | 1319.945 | 1812.402 | 1186.636 | 1465.409 | 1054.125 | 1110.636 | 931.695 | 1106.571 | 1258.755 | 1134.763 | 748.655 | 886.936 | 866.66 |
| | 1 | 1606.042 | 1506.662 | 1262.348 | 1383.603 | 1073.379 | 1437.985 | 1479.704 | 1317.822 | 1149.982 | 1165.768 | 1177.667 | 1237.185 | 1062.7 |
| | Absolute | 1469.213 | 1652.885 | 1226.138 | 1422.728 | 1064.17 | 1281.427 | 1217.613 | 1216.789 | 1202.003 | 1150.939 | 972.487 | 1069.675 | 968.942 |
| | Geometric | 1,463.0 | 1,659.5 | 1,224.5 | 1,424.5 | 1,063.8 | 1,274.3 | 1,205.7 | 1,212.2 | 1,204.4 | 1,150.3 | 963.2 | 1,062.1 | 964.7 |
| FM02 | 0 | 283.9014 | 316.7457 | 290.8664 | 328.5622 | 299.8543 | 291.8393 | 260.71 | 274.1471 | 274.2072 | 254.5593 | 318.8178 | 292.755 | 273.5443 |
| | 1 | 364.7067 | 404.4011 | 291.0833 | 356.4567 | 327.7133 | 306.0689 | 296.1922 | 326.7589 | 285.6956 | 367.6567 | 419.2155 | 346.6356 | 341.4544 |
| | Absolute | 315.5209 | 351.0456 | 290.9513 | 339.4774 | 310.7557 | 297.4074 | 274.5943 | 294.7343 | 278.7026 | 298.8148 | 358.1039 | 313.8387 | 300.1178 |
| | Geometric | 324.30 | 360.57 | 290.97 | 342.51 | 313.78 | 298.95 | 278.45 | 300.45 | 279.95 | 311.11 | 369.02 | 319.70 | 307.50 |
| FM03 | 0 | 1.648 | 2.029 | 1.407 | 2.295 | 1.460 | 1.677 | 1.598 | 1.615 | 1.877 | 1.924 | 1.452 | 1.403 | 1.551 |
| | 1 | 1.441 | 1.452 | 1.573 | 1.421 | 2.215 | 1.479 | 2.512 | 1.475 | 1.365 | 1.460 | 1.645 | 1.575 | 1.363 |
| | Absolute | 1.558 | 1.777 | 1.480 | 1.913 | 1.790 | 1.590 | 1.998 | 1.554 | 1.653 | 1.721 | 1.537 | 1.478 | 1.469 |
| | Geometric | 1.545 | 1.741 | 1.490 | 1.858 | 1.837 | 1.578 | 2.055 | 1.545 | 1.621 | 1.692 | 1.549 | 1.489 | 1.457 |
| FM04 | 0 | 30.52053 | 31.94844 | 27.72068 | 33.37014 | 30.8994 | 34.34892 | 31.91694 | 34.27641 | 36.06374 | 28.6927 | 30.86742 | 29.25893 | 35.93007 |
| | 1 | 30.20099 | 28.71545 | 31.76053 | 35.75195 | 31.45153 | 34.72738 | 33.44693 | 28.67604 | 32.2869 | 36.44196 | 34.90463 | 31.57219 | 30.06647 |
| | Absolute | 30.38073 | 30.53401 | 29.48811 | 34.41218 | 31.14096 | 34.5145 | 32.58631 | 31.82625 | 34.41137 | 32.08337 | 32.6337 | 30.27098 | 33.36475 |
| | Geometric | 30.36 | 30.33 | 29.74 | 34.56 | 31.18 | 34.54 | 32.68 | 31.48 | 34.18 | 32.57 | 32.89 | 30.42 | 33.00 |
| FM-A | 0 | 16.11111 | 12.66667 | 12.16667 | 17 | 14.83333 | 17.61111 | 15.72222 | 12.77778 | 14.55555 | 15.72222 | 14.83333 | 12.55556 | 15.05556 |
| | 1 | 16.71429 | 16.35714 | 17 | 14.21429 | 13.85714 | 15 | 11.07143 | 11.07143 | 14.21429 | 12.28571 | 9.14286 | 16.21428 | 10.92857 |
| | Absolute | 16.375 | 14.28125 | 14.28125 | 15.78125 | 14.40625 | 16.46875 | 13.6875 | 12.03125 | 14.40625 | 14.21875 | 12.34375 | 14.15625 | 13.25 |

| | | 16.41 | 14.51 | 14.58 | 15.61 | 14.35 | 16.31 | 13.40 | 11.92 | 14.38 | 14.00 | 11.99 | 14.38 | 12.99 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Geometric | 16.41 | 14.51 | 14.58 | 15.61 | 14.35 | 16.31 | 13.40 | 11.92 | 14.38 | 14.00 | 11.99 | 14.38 | 12.99 |
| FM-B | 0 | 469.7222 | 347 | 395.3889 | 439.4445 | 422.2222 | 489.3333 | 437.5556 | 306.2778 | 438.6111 | 477.5556 | 454.7778 | 353.9445 | 450.7778 |
| | 1 | 409.5 | 374.5714 | 434 | 355.1429 | 364.2857 | 334.2857 | 263.8571 | 254.4286 | 331.1429 | 300.7143 | 239.7143 | 459.7857 | 263 |
| | Absolute | 443.375 | 359.0625 | 412.2813 | 402.5625 | 396.875 | 421.5 | 361.5625 | 283.5938 | 391.5938 | 400.1875 | 360.6875 | 400.25 | 368.625 |
| | Geometric | 439.61 | 360.79 | 414.69 | 397.29 | 393.25 | 411.81 | 350.71 | 280.35 | 384.88 | 389.13 | 347.25 | 406.87 | 356.89 |

0 = >250 Hours
1 = <250 Hours

# APPENDIX 10

## DATA PLOTS FOR DEPENDENT VARIABLES THAT
## DID NOT DIFFER SIGNIFICANTLY

### ALTITUDE DEVIATION - STRAIGHT AND LEVEL FLIGHT
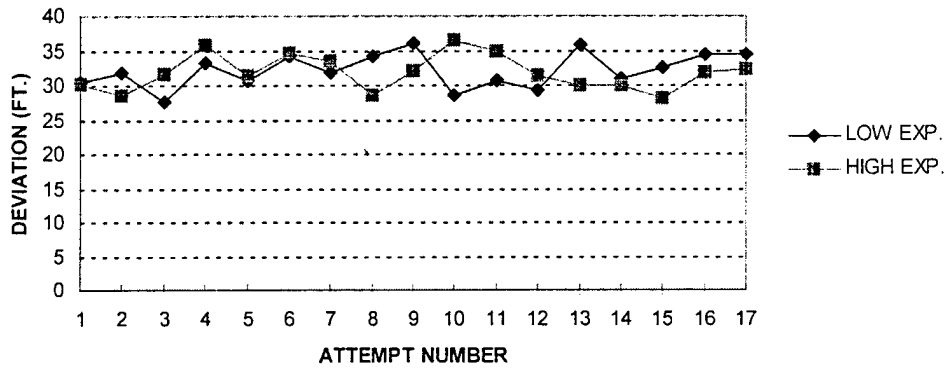


### HEADING DEVIATION - STRAIGHT AND LEVEL FLIGHT
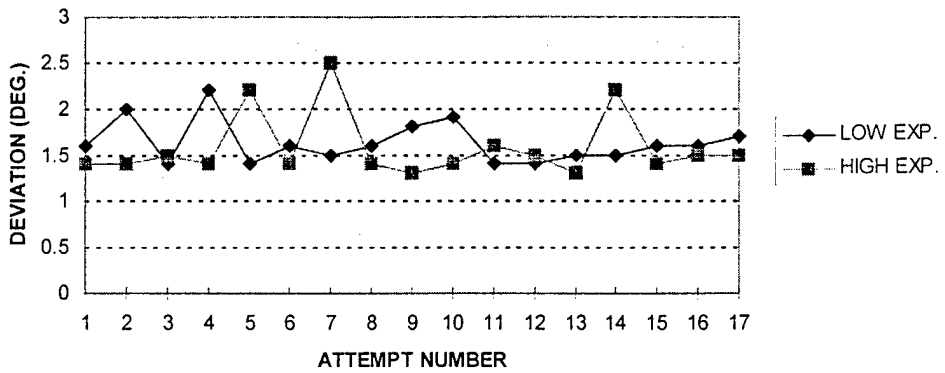
## DEVIATION FROM ASSIGNED ALTITUDE FOR ROLLOUT ON GROUND ATTACK MISSION
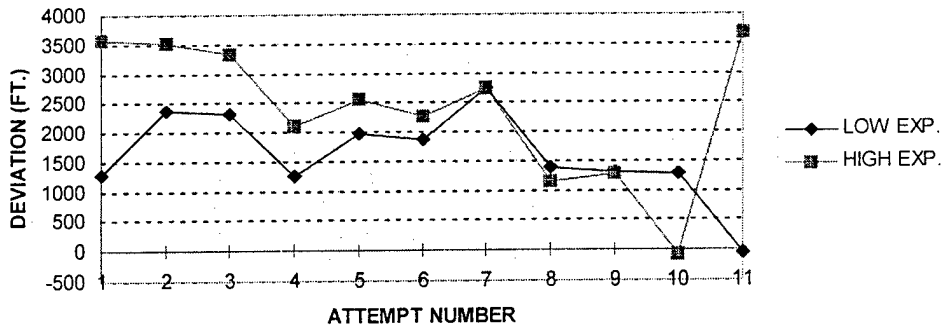


## DEVIATION FROM ASSIGNED ALTITUDE FOR INITIATING LEFT TURN
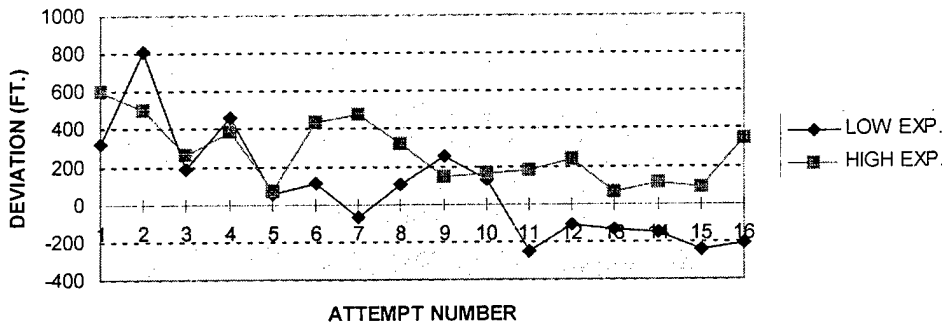
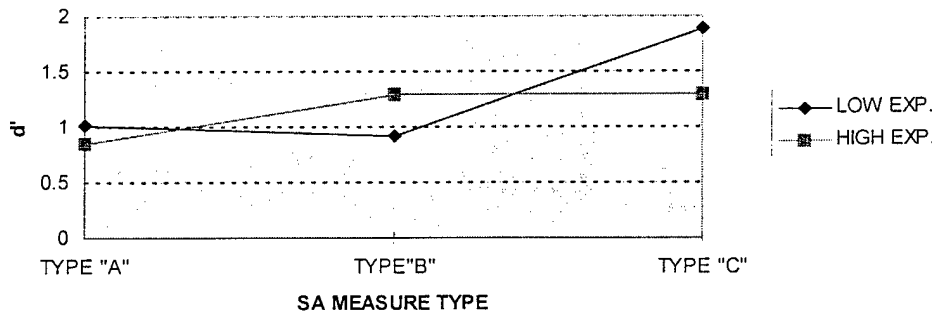## DEVIATION FROM ASSIGNED SPEED AT SELECTION OF MIL-POWER
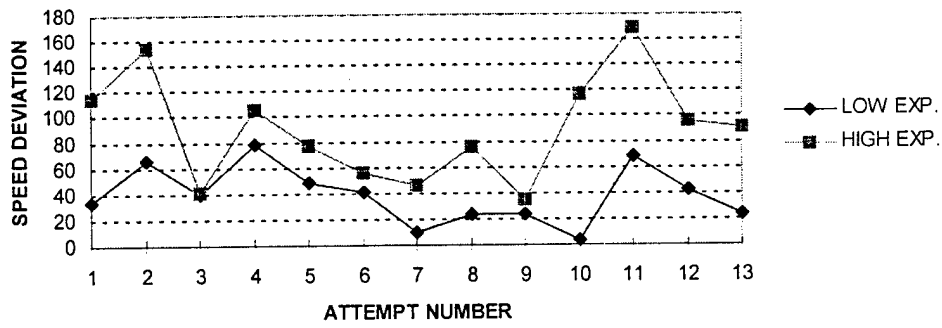


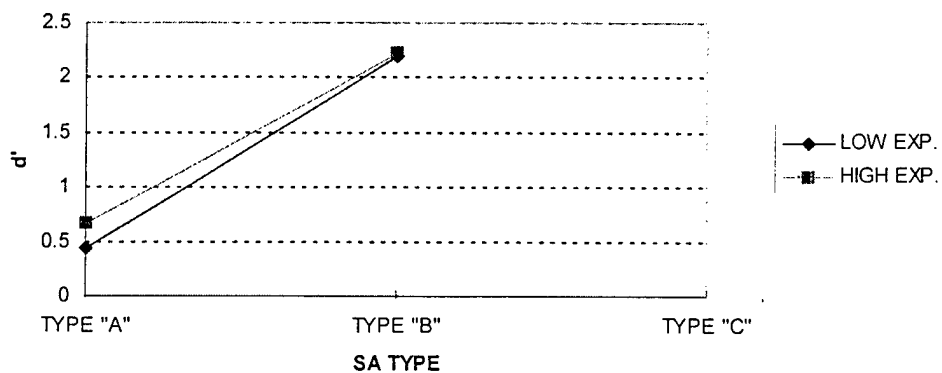## d' SA MEASURES FOR GROUND ATACK MISSIONS - LOW EXPERIENCE SUBJECTS
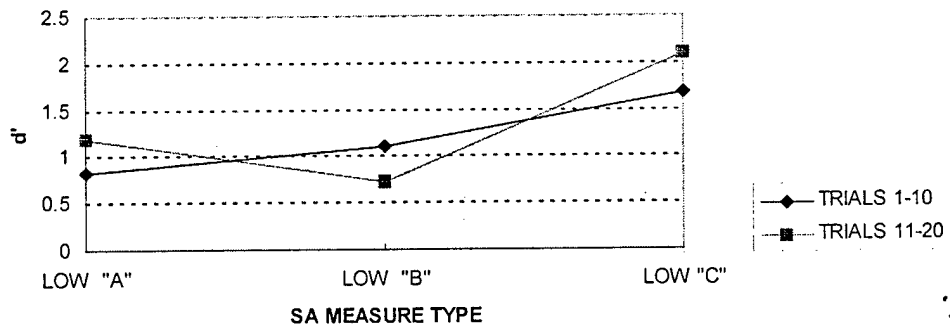
# SA MEASURES FOR GROUND ATTACK MISSIONS - HIGH EXPERIENCE SUBJECTS
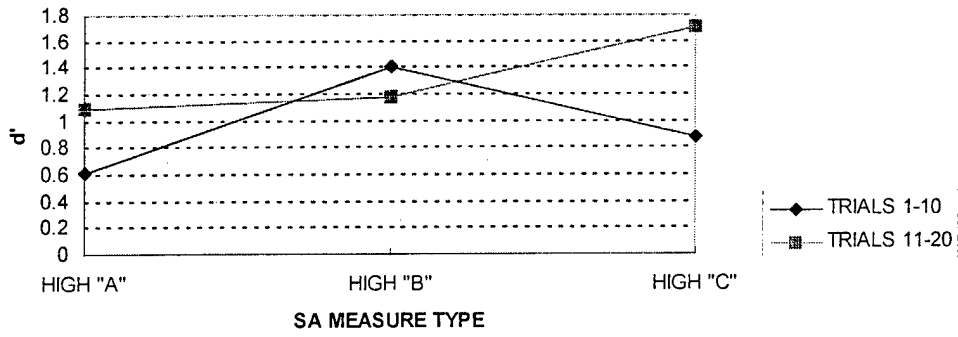


# d' SA MEASURES FOR GROUND ATTACK MISSION BY EXPERIENCE LEVEL

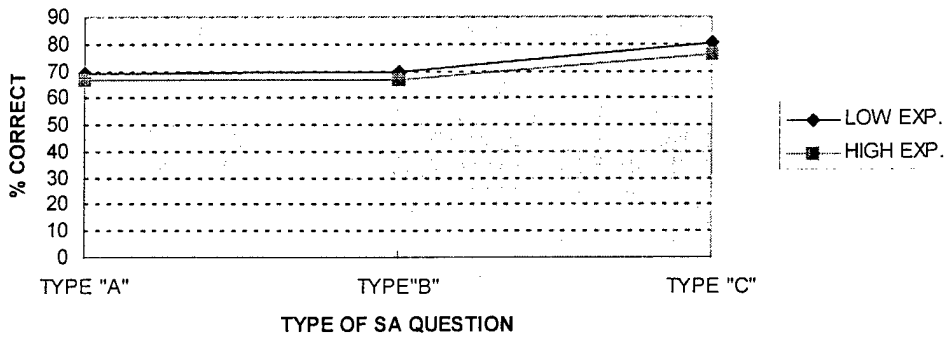d' SA MEASURES FOR S-TURNS BY EXPERIENCE LEVEL



SA QUESTIONS PERCENT CORRECT FOR GROUND ATTACK
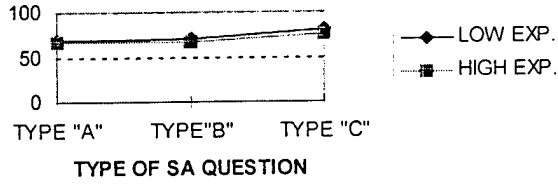MISSIONS - LOW EXPERIENCE SUBJECTS
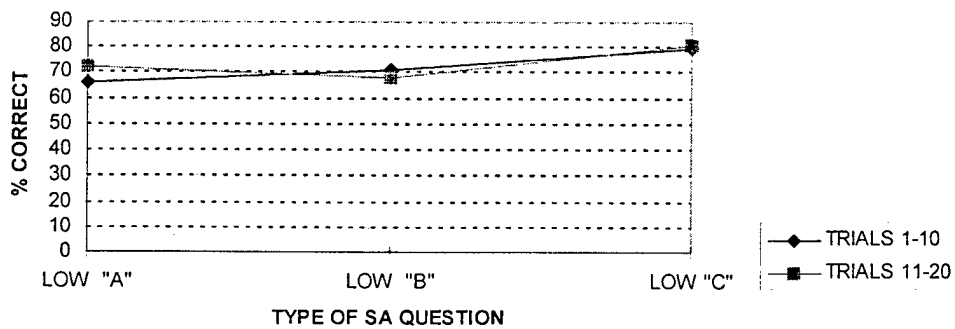
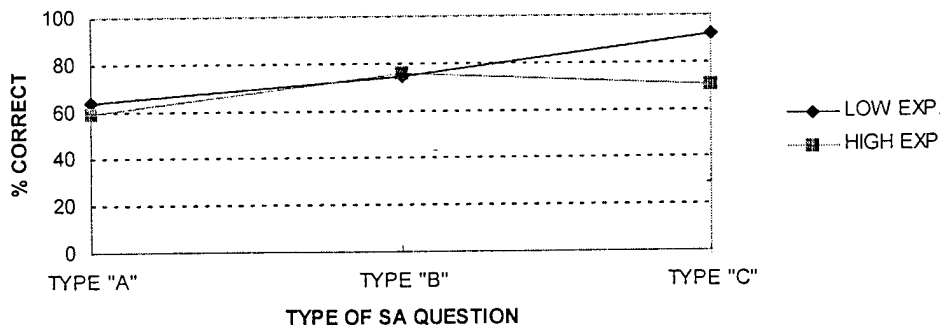## SA QUESTIONS PERCENT CORRECT FOR GROUND ATTACK MISSIONS - HIGH EXPERIENCE SUBJECTS
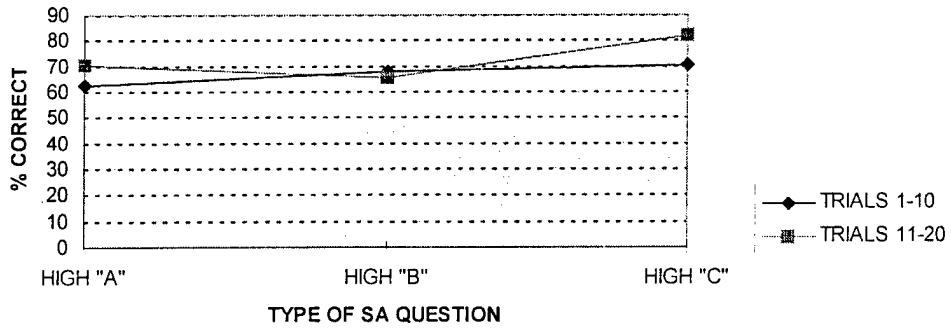


## SA QUESTIONS PERCENT CORRECT FOR GROUND ATTACK MISSIONS BY EXPERIENCE LEVEL
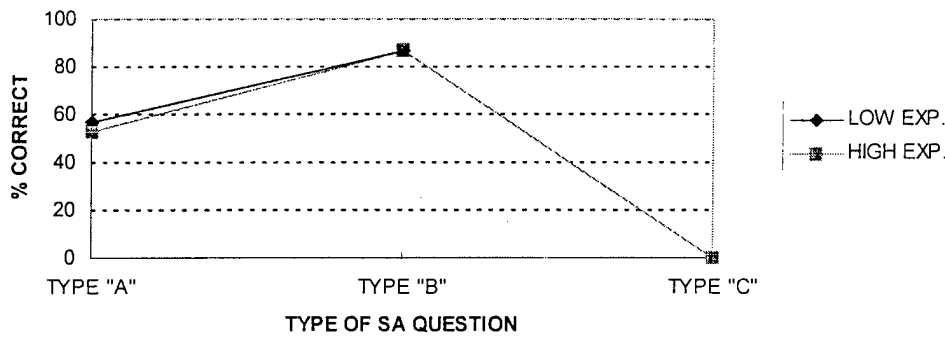
## SA QUESTIONS PERCENT CORRECT FOR GROUND ATTACK MISSIONS BY EXPERIENCE LEVEL



## SA QUESTIONS PERCENT CORRECT FOR CAP MISSIONS BY EXPERIENCE LEVEL

# SA QUESTIONS PERCENT CORRECT FOR S-TURNS BY EXPERIENCE LEVEL



X-axis: TYPE OF SA QUESTION (TYPE "A", TYPE "B", TYPE "C")
Y-axis: % CORRECT

Legend: LOW EXP., HIGH EXP.

| Custom Search | BASIC Search | List |
|---|---|---|

## DoD SBIR / STTR
## DETAILS - Awards Search Results

**Program:** SBIR

**Agency:** AF

**Field Office:** AL

**TOPIC Number:** AF94-032

**Control Number:** 94AL -338

**Contract Number:** F41624-95-C-5008

**Phase:** 2

**Awarded In:** 95

**Award Amount:** $671,892

**Award Start Date:** 07MAR95

**Award Completion Date:** 07MAR97

**Proposal Title:** Development of the Low-Cost Situation Awareness Flight Trainer Evaluator (SAFTE)

**Principal Investigator Name:** Robert D. O'Donnell, Ph.D

**Principal Investigator Phone:** 513-254-3171

## Firm

NTI, INC.
4130 Linden Ave
Dayton, OH 45432

**Woman Owned:** N
**Minority Owned:** N
**Number of Employees:** 7

**Keywords:** SITUATION AWARENESS FLIGHT TRAINING SYNTHETIC TASK FLIGHT SIMULATOR SITUATION AWARENESS EVALUATION