STUDENT PILOT SITUATIONAL AWARENESS:
THE EFFECTS OF TRUST IN TECHNOLOGY

by

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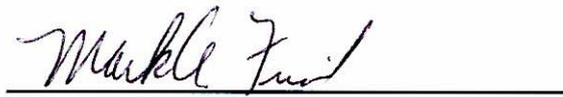Master of Science in Aeronautics.
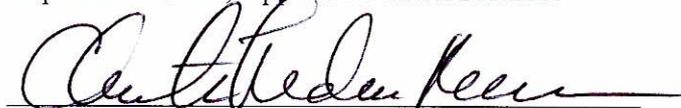
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ABSTRACT

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The purpose of this research was to evaluate the general level of trust in technology in student pilots and then to determine the relationship between pilots' trust and their situational awareness during simulated flight. A literature review revealed that the Jian Trust Scale was based on empirical observations and had precedence in the literature so it was selected. Since excessive reliance on technology can make the operator passive and unquestioning, ultimately loss of situational awareness may result. The main hypothesis tested was to establish the relationship between measurements of trust on the ground and situational awareness in simulated flight; pilots who had lower-trust in technology were expected to have to maintain higher levels of situational awareness. Conversely, higher-trust pilots were expected to have lower situational awareness due to an over reliance on the equipment. Instructor pilots rated the 30 students in simulated flight using a modified Situation Awareness Global Assessment Techniques (SAGAT) score and this was compared to their Trust score derived from ground based testing. The results were opposite from those expected but significant facts were discovered. The pilots with the highest trust scores showed the best situational awareness. This study concludes that the trust is not blind in ERAU pilots, they seem to trust the instruments and yet also maintain good situational awareness. The results were not as clear for the middle trust scoring pilots and suggests that trust and situational awareness are not as related. The need for

monitoring situational awareness is discussed and the use of a simple and rapid ground based trust score may indicate which students would most benefit from improving their situational awareness would be the middle scorers on a trust scale. The simplicity of this approach to identifying those in need of improving situational awareness and the successful prediction of high trusting pilots and good situational awareness, suggests that a better trust scale, one geared specifically for general aviation, would be useful.

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LIST OF ACRONYMS

ADM   Aeronautical Decision Making

ATC   Air Traffic Control

CRM   Crew Resource Management

GPS   Global Positioning Systems

FAA   Federal Aviation Administration

FITS   FAA/Industry Training Standard

IFR   Instrument Flight Rules

LOFT   Line Oriented Flight Training

MFD   Multi Function Displays

NAS   National Airspace System

PFD   Primary Function Displays

SAGAT   Situation Awareness Global Assessment Technique

SRM   Single-Pilot Resource Management

TAA   Technically Advanced Aircraft

VOR   VHF Omni Directional Range Station

CHAPTER I

INTRODUCTION

Background and Significance

The ability of pilots to maintain situational awareness, the awareness of their position and direction in space, their proximity to the ground and other aircraft, are critical to their survival and that of their passengers. Even the best trained and most experienced pilots can make poor decisions, and these poor decisions are spawned from poor situational awareness (Endsley, 1990). A new generation of aircraft is emerging with technical aids to navigation that measurably improve situational awareness with enhanced, real-time computerized displays of aircraft and navigation information. If operating correctly, these instruments remarkably improve pilot situational awareness (SA) and promise to improve safety of flight. What if these instruments fail however, and worse, what if their failure is not complete and inaccurate information is still communicated? Worse still, what if the pilot does not notice this error because of a trust in the accuracy and reliability of the computerized equipment? This paper concerns itself with how levels of trust placed in technology affect situational awareness. The study aims to bring to light risks that may arise as a result of too much trust in technology; situations that may arise when the pilot is lulled into a false sense of complete security in the computerized display. There may be an improvement in situational awareness but is there a cost in the event of over reliance on our computers.

"Situational awareness" is formally defined as "a perception of the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988, p. 97). All of the incoming

data from aircraft systems, the outside environment, fellow crew members, other aircraft, and Air Traffic Control must be brought together into an integrated whole. Situational awareness is a critical mental process, and it affects decision-making and performance (Endsley, 1996).

Workload and distraction also are critical tasks management skills, particularly to single pilot resource management of the flight operation. Task delegation to automation systems is time-saving for the pilot, particularly with increased workload or increased distractions. Collecting all the information from all the available resources is an essential piloting ability, and at the same time accurate data interpretation is equally important. Keen attention to detail could save time in detecting an error. In high workload environments, attention is consumed by the situation and errors may go undetected, particularly errors that are not annunciated well. Some pilots may be more susceptible to this failure to notice errors, just like pilots seem to differ in their level of situational awareness.

Endsley stresses that situational awareness constructs can be broken down into three levels: perception of the situation (Level 1), comprehension of the situation (Level 2), and projection of future (Level 3) (Endsley 1988). Understanding and quickly interpreting the current situation status as well as projecting the future are also critical to maintaining the pilots' situational awareness. Anticipating what will happen with the plane, the path, and the people involved if the current situation continues are also key in maintaining high levels of situational awareness. Considering what to do if he or she has to make a missed approach, if the weather deteriorates at the destination are important.

It may be possible to improve situational awareness by training. Situational awareness training may take place through Crew Resource Management (CRM), Line Oriented Flight Training (LOFT), and emergency exercise training. Even the most experienced and talented pilots can make the wrong decision if they have inaccurate situational awareness. This applies to noticing equipment malfunction as well as noticing position and future position in space. Conversely, a pilot may accurately understand what is occurring in the environment yet not know the correct action to take or be unable to carry out that action (Endsley, 1990), particularly if given the wrong information.

Finally, highly- automated craft are entering the general aviation fleet in large numbers. Aircraft equipped with highly automated systems such as Global Positioning Systems (GPS), Primary Flight Displays (PFD) and Multi Function Displays (MFD) are made to improve safety and are appearing in unprecedented numbers for a new technology. General aviation pilots can be expected to have more experience in automated aircraft from the earliest periods of flight so that they will be able to easily transition to airline pilot training; however, such aircraft may create a different level of human error. The AOPA Air Safety Foundation (2005) has already found that a higher percentage of low-time pilots are having accidents in highly- automated aircraft. Our culture accepts automation and computers as infallible. This is a problem because automation takes over many piloting responsibilities and dependence on the system may compromise situational awareness. For example, pilots believe the machine is doing its job very well, and peruse other tasks inside the cockpit while monitoring is overlooked. The degree to which a pilot trusts his equipment, particularly technical electronic equipment, might be measurable. Pilots prone to passive system monitoring might be

forewarned by an individual evaluation of their trust level. For example, if a pilot takes a simple simulator test in an automated aircraft their trust level can be assessed and scored so that the pilot can take corrective action before a problem occurs.

Much of today's flight training is oriented towards enhancing situational awareness. Improving situational awareness for general aviation pilots may improve aviation safety overall. General Aviation pilots with 100 to 500 hours of total time have contributed the greatest number of accidents (Wells, 1992). According to Trollip and Jensen (1991)'s profile, there is a period between 100 to 500 hours in which pilots' confidence level exceeds their ability level. They also suggested two periods that are particularly dangerous: (1) approximately 100 hours, after the pilot has accumulated about 50 hours beyond the private pilot's certificate, and (2) between 50 to 100 hours after earning an instrument rating. Those two periods are marked by an increase in confidence without a substantial experience gain. It appears that an appropriate situational awareness training intervention strategy would be necessary at this stage, after basic flight skills have been acquired but an in-depth level of expertise on which to build situational awareness has not yet been accumulated (Endsley, Garland, & Georgia, 2000).

Automation was developed to help improve aviation safety by relieving pilot workload thereby, presumably, enhancing situation awareness. For single pilot operation, automation systems such as GPS, MFD, and the other advanced avionics make effective decisions for the pilot and help reduce the pilot's workload. Some automation systems are amazingly intelligent and help make a decision for a pilot. However, these systems are only decision-making aids to help pilots. The pilots still remain as final decision makers. Furthermore, those automation systems fail from time to time. If a pilot depends on a

system too much and does not pay attention to clues that the system may not be working properly, the pilot will interpret the data as accurate. Good situational awareness should include some skepticism about the information the pilot receives, whether from the pilot's biological sensory systems, as in the case of disorientation, or in the case of system disorientation from instrument failure.

Automation seems like it is making pilots become less perceptive. Bergeron (1981) noted that pilots working with increased levels of automation in an autopilot were more likely to lose track of where they are (Endsley & Kiris, 1995). This fact is called the man-out-of-the-loop performance problem. According to Endsley and Kiris (1995), the out-of-the-loop performance problem is a major potential consequence of automation. This leaves operators of automated systems handicapped in their ability to take over manual operations in the event of automation failure. System operators working with automation have been found to have a diminished ability both to detect system errors and subsequently to perform tasks manually in the face of automation failures, compared with operators who manually perform the same tasks (Endsley, Bolté & Jones, 2003).

There are many other potential dangers with the use of the automation systems, including mode misunderstandings and errors, failures to understand automation behavior, confusion or lack of awareness concerning what automated systems are doing and why, and difficulties tracing the functioning or reasoning process of automated agents (Billings, 1996; Sarter & Woods, 1993). Research into the relationship between human use of technology and trust of that technology has found a relationship between task workload and trust. A review by Biros, Daly and Gunsch (2004) found that at high workload levels there tends to be an over reliance on automation. Overtrust in automation

has produced errors in many settings such as target detection and system failures (Wickens, Conejo, and Gempler, 1999; Mosier, Skitka, Heers, and Burdick, 1998). There are similar conclusions drawn from medicine in which automation is increasingly producing diagnostic decision aides for medical personnel (Wiegmann, Rich, Zhang, 2001).

Pilots' trust in automation would seem to have a great influence on the likelihood of catching and correcting an equipment malfunction. Similarly, it may follow that the pilot who has a high level of trust in the automated equipment may begin to omit tasks that should be monitored because the pilot overly trusts the equipment. This action may allow the pilot to overlook important situational information. There is no clear way to demonstrate how much trust a pilot needs toward a system; however, trusting a system too much will affect the operator's situational awareness, will create an over-reliance. If a pilot over-trusts the systems, he/she may misperceive the instruments, may rarely look at the instruments, and may mistakenly interpret data. Assuming that the system is highly reliable could make pilots passive, and the systems are less likely to monitor. As pilot becomes a passive monitor, they may tend not to notice when the systems are not working properly or even may miss the information due to inattention. If the pilot's trust changes the way pilots perform tasks, interacts with the equipment and makes decisions, his/her trust may influence the usage of other resources such as traditional instruments, weather, Air Traffic Control, other crew members, and many other resources available to the pilot (Endsley, Bolté & Jones, 2003).

Trust has been studied mostly in the social psychology field (Jian, Bisantz & Drury, 2000). Rather than human- to- human trust, Jian, Bisaniz, and Drury (2000)

studied trust between human and machine. The trust scale that was used in this study was basically for measuring trust levels between human and machine in general. They developed a trust scale for measuring human-machine trust through a very thorough word selection based on their elaborate experiments.

Endsley (1987) introduced the Situation Awareness Global Assessment Technique (SAGAT) to assess situational awareness across all of its elements based on a comprehensive assessment of operator situational awareness requirements. It allows one to measure operators' situational awareness subjectively, and it is able to obtain data of the operators' current perceptions of the situation. So far this technique is the most effective and subjective measurement of pilots' situational awareness.

The data from those two measurements, one of trust and one of SAGAT will be compared to observe whether trust level affects pilots' situational awareness. Measuring trust itself is already a big challenge. The benefits of attempting this approach are clear. If trust towards flight automation can be measured in a pilot, that is if over reliance on instruments can be ascertained, and if a relationship between trust and situational awareness can be determined then it may be possible to assess situational awareness from trust scales alone, on the ground. Pilots could be alerted that they may have an over reliance on their systems, they might trust too much and fail to notice an instrument malfunction or may miss important information because they know the machines are taking care of it. The machines may have great situational awareness but an over trusting pilot may not. This would be a new way of measuring situational awareness toward systems and could be a convenient new tool for pilots' training, building a healthy

skepticism regarding automation and reducing the reliance on automation for critical monitoring tasks. Trust the instruments certainly, but not blindly.

This study will help understand and will attempt to predict patterns of automation bias based on a pilots' level of trust. This study may lead to the development of a trust scale between human and computerized aircraft systems.

Problem Statement

A pilot's trust in automation systems is related to the effective use of such systems. Bias caused by the pilot's trust in the machine may significantly affect their situational awareness. Since many pilots are not familiar with monitoring and controlling the multiple tasks presented in today's complex automated flight systems, it could be difficult for them to maintain high levels of situational awareness. In high workload conditions, pilots' over-reliance on aircraft operation systems may have a great impact on their use of the automations systems. The relationship between a pilot's trust level for automated systems and their reliance on the instruments might indicate their level of potential situational awareness in flight. A pilot predisposed to trust computers may be less likely to observe them and may miss information that provides for good situational awareness.

This research investigated the relationship between novice pilots' trust of aircraft systems (not limited to automation) and their situational awareness. This study has implications for the FAA/Industry Training Standard (FITS) program to prevent accident/incident, and to improve safety for novice pilots in high technology aircraft. The trust level of novice pilots will be measured on the ground, and compared with their situational awareness in real-time simulated flight. Correlations between trust and

situational awareness will then be determined. It is expected that pilots who overtrust their automated instruments will not attend to them as well and will be deficient in their situational awareness. The end result will hopefully be helpful in raising the competency of general aviation pilots by determining the degree to which trust in automation may affect their situational awareness.

CHAPTER II

REVIEW OF THE LITERATURE

The advance of computer processing power and information display systems are evident in technically advanced aircraft, and have redefined many tasks for humans. For example, the analog gauges that grew up with the airplane and became standardized are rapidly being replaced by computerized displays that are more accurate, informative and reliable. With the proper training, these new aircraft displays promise to reduce the burden and tedium of many piloting and navigation demands on the pilot and make general aviation safer. This is the goal of the FAA/ Industry Training Standard (FITS) project, to facilitate the introduction of cockpit automation through training recommendations and improve general aviation safety (Landsberg, 2003). However, the introduction of automation may have hidden dangers for pilot performance by encouraging an over reliance on automation, what has been called 'overtrust' of automation (Davision, Wickens, 2001). Pilots may be lulled into underactivity and fail to monitor completely automated systems on their displays or overtrust these instruments during high workload conditions while their attention is drawn elsewhere. This could lead to a diminution of the improvement in situational awareness expected in technically advanced aircraft (TAA).

TAA are entering the general aviation fleet in large numbers (AOPA Air Safety Foundation, 2005, p. 1). TAA are identified as aircraft that are sufficiently different from traditional general aviation aircraft in navigation and instruments particularly in the use of computerized displays (AOPA Air Safety Foundation, 2005). FAA's TAA Safety Study Team (2003) defined a TAA as "an aircraft that has at a minimum: Instrument

Flight Rules (IFR) certified Global Positioning System (GPS) navigation equipment

(navigator) with a moving map; or a multi-function display (MFD) with weather, traffic

or terrain graphics; and an integrated autopilot (p. 9)." In general, the pilot interfaces with

one or more computers in order to aviate, navigate, or communicate in TAA (FAA TAA

Safety Study Team, 2003). The AOPA Air Safety Foundation (2005) defined a TAA as

an aircraft with a cockpit equipped with new generation avionics that takes full advantage

of computing capability, modern navigational aids to improve pilot positional awareness,

system redundancy, and in-cockpit information.

Most TAA aircraft are older, traditional general aviation aircraft that have

undergone a transformation through substantial navigation, communication, and display

system (avionics) upgrades. In addition, "new-production" TAAs, such as the Cirrus

Design Corporation (Cirrus) SR 20 and SR 22 and the Columbia Aircraft Company

350/400, are entering the fleet in increasing numbers (FAA TAA Safety Study Team.,

2003)

The TAA conversion goes beyond just equipment. The larger definition includes

a new mindset for pilots, encompassing a revised view of what constitutes general

aviation flying. Flying TAA is flying with airline style procedures, regular use of the

autopilot, and greater dependence on avionics for multi tasking beyond pure navigation

(AOPA Air Safety Foundation, 2005).

The TAA is a high-tech aircraft made to improve safety, yet this aircraft creates

a different level of human errors. TAA Safety Study Team (2003) states that typical

problems occurred after previous introductions of new aircraft technology. TAA also

reflect typical general aviation pilot judgment errors found in analysis of non-TAA

related accidents. The AOPA Air Safety Foundation (2005) has found that a higher percentage of low time pilots are having accidents in TAA. This team observed that in some cases, pilots tended to have an unwarranted over reliance on their equipment which they believed would compensate for their piloting shortcomings. System management skills must come with basic stick and rudder skills; they concluded.

FAA/Industry Training Standard Criteria

FAA/Industry Training Standard (FITS) is a joint research program developing general aviation pilot training in TAA. TAA require an emphasis on realistic, scenario-based training to develop the higher- order thinking skills required to reduce the number of general aviation accidents and incidents. The goals of FITS also include improving pilot knowledge on safely, competently, and efficiently operating technically advanced piston or light jet aircraft in the modern National Airspace System (FAA/Industry Training Standards, 2004).

In order to achieve these goals, and to account for the TAA recently introduced in general aviation, a new training style must be adopted. Specific training goals include enhancing higher-order thinking skills, including aeronautical decision-making (ADM), situational awareness, and pattern recognition (FAA/Industry Training Standards, 2004). Other skills included within the FITS training goals are automation competence, planning and execution, procedural knowledge, and psychomotor skills (FAA/Industry Training Standards, 2004).

Trust in Automation

Computer-assisted technologies are growing at an accelerated pace in aircraft, ocean vessels, healthcare and elsewhere in complex technical environments where human

failure might be relieved. The opposite side of that reduction in human error these systems promise is over trust and the growing phenomenon of complacency in systems operations (Atoyan, Duquet and Robert, 2006). The level of trust has been shown to be a primary influence on successfully using automation systems (Jian, Bisantz, & Drury, 2000). There is no evidence how much trust is too much or how much is not enough. There are many automation- related accidents or mishaps in commercial aviation. In 1972, an Eastern Airlines aircraft accident may have been the result of an automation omission error. While the crew was determining the reason why the landing gear indicators did not work even though the landing gears were down, the crew was unaware the autopilot was disengaged until prompted by Air Traffic Control to check their altitude. By the time they had descended to 30 ft above ground level, it was too late to make a correction (Billlings, 1996).

In 1983, Korean Airlines 007 flew into Soviet airspace, and was shot down by Soviet fighters. The crew did not follow their intended flight-path; instead they maintained a magnetic heading until they were destroyed as a threat. The crew was relying entirely on automation. Although the automation system had been inappropriately set up, the crew never checked their progress manually ("Analysis of Flight Data," 1993). If the operators do not trust the automation system, the systems will likely be unused. The operators will lose the benefits for which the systems were designed. On the other hand, overused and overly automated systems may be monitored less frequently (Muir & Moray, 1996). Even if occasional faults occur, the trust in automation can continue to be a profound influence on decision making of an operator (Lee & See, 2004). These automation biases could create serious problems in situational awareness, and ultimately

affect the crews' decision-making process. Automation bias needs to be removed in order to have effective situational awareness that aids the decision-making process (Mosier, Skitka, Heers, & Burdick, 1998).

Definitions of "Trust"

Madsen and Gregor (2000) define "trust in automation" as "the extent to which a user is confident in and willing to act on the basis of the recommendations, actions and decisions of a computer-based tool or decision aid". It is important to point out that the "trust" referred to here is the "trust in automation" not the term for human- to- human relationships. Some researchers focus on "trust" as an attitude or expectation, and they tend to define "trust" in one of the following ways: "Expectancy held by an individual that the word, promise or written communication of another can be relied upon" (Rotter, 1967, p. 651), "[An] expectation related to subjective probability an individual assigns to the occurrence of some set of future events" (Rempel et al., p. 95), "[An] expectation of technically competent role performance" (Barber, 1983, p. 14), or "[An] expectation of fiduciary obligation and responsibility, that is, the expectation that some others in our social relationships have moral obligations and responsibility to demonstrate a special concern for others' interests above their own" (Barber, p. 14). These definitions all include the element of expectation regarding behaviors or outcomes. Clearly, trust is concerned with expectancy or an attitude regarding the likelihood of favorable responses. Another outcome approach characterizes trust as an intention or willingness to act. This goes beyond attitude, in that trust is characterized as an intention to behave in a certain manner or to enter into a state of vulnerability. For example, "trust" has been defined as a "willingness to place oneself in a relationship that establishes or increases vulnerability

with the reliance upon someone or something to perform as expected" (Johns, 1996, p. 81), a "willingness to rely on an exchange partner in whom one has confidence" (Moorman et al., 1993, p. 82), and a "willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the truster, irrespective of the ability to monitor or control that party" (Mayer, Davis, & Schoorman, 1995, p. 172). "Vulnerability" is identified as a critical factor of trust. Individuals must willingly put themselves at risk or in vulnerable positions by delegating responsibility for actions to another party (Lee & See, 2004).

Ajzen and Fishbein (1980) introduced a framework in which behaviors result from intentions, and those intentions are functions of attitudes. Attitudes in turn are based on beliefs. According to the framework, "Beliefs and perceptions represent the information base that determines attitudes. The availability of information and the persons' experiences influences beliefs. An attitude is an affective evaluation of beliefs that guide people to adopt a particular intention. Intentions then translate into behavior, according to the environmental and cognitive constraints a person faces" (Lee & See, p. 53). Moreover, trust is an attitude, and reliance is a behavior. This framework keeps beliefs, attitudes, intentions, and behavior conceptually distinct and can help explain the influence of trust on reliance. Trust affects reliance as an attitude rather than as a belief, intention, or behavior (Lee & See, 2004).

Castelfranchi and Falcon (1998) studied the relationships among trust, reliance, and delegation. They quoted the definition of "trust" from Gambetta: "'Trust' is the subjective probability by which an individual, A, expects that another individual, B, performs a given action on which its welfare depends." Castelfranchi and Falcon stressed

that trust is a mental state and an attitude towards another agent. It is basically an estimation, an opinion, an evaluation, i.e. a belief. Additionally, they described that "reliance" is necessary for the mental state, and only "delegation" is necessary for the action of relying and trusting (Castelfranchi & Falcon).

The delegation process may also play an important role in the relationships between human and automation systems as a part of the decision-making process. The definition of delegation by Castelfranchi and Falcon is that A trusts both in B's ability and predictability in order to achieve A's goal. Strong delegation depends on B's awareness of A's intention to exploit his action; normally it is based on B's adapting to A's goal. There are many critical factors influencing the trust process.

Baber (1993) defined "trust between human and machine" as "our general expectation of the persistence of the natural physical order, the natural order, and the moral social order, and our specific expectation of technically competent role performance from those involved with us in social relationships and systems." Based on these definitions, Muir (1994) proposed that human-machine trust has three stages of development: predictability, dependability, and faith. Humans develop trust in a machine by determining its consistency and desirability of its repeated behavior over a given period of time. The predictability leads to dependability as the relationship develops. Based on these two stages, faith develops. Humans develop faith only after working with a machine for a significant amount of time (Muir 1994). After working with the machine long enough to become familiar with it and one sees that it can operate it without any supervision, his or her dependability will be changed, depending on how many failures he or she faces during the machine operation. If the machine always works appropriately,

one will predict the machine is highly reliable.

Based on Barber (1983)'s and Rempel et al. (1985)'s sociologist definitions of "trust", Muir (1989) defined "trust" as the subjective expectation of future performance and described three types of expectation related to the three dimensions of trust: persistence in upholding natural and moral laws, technically competent performance, and fiduciary responsibility. According to Barber, persistence in upholding natural and moral laws is the basis of the other two dimensions, and providing a foundation of trust is attained by establishing constancy in the fundamental natural and moral laws. This stage reflects the belief that '… the heavens will not fall,' and that '… my fellow man is good, kind, and decent' (Barber, p. 9, and Lee & Moray, 1992).

On the other hand, technically competent performances support expectations of future performance, based on capabilities, knowledge, or expertise (Lee & Moray). This dimension seeks the ability of the other partner to produce consistent and desirable performance (Lee & Moray). The last dimension of trust, "fiduciary responsibility", is concerned with the expectation that people have moral and social obligations to hold the interests of others above their own. This added dimension extends the idea of trust being based on performance to trust being based on moral obligations and intentions. These expectations depend on an assessment of the intentions and motivations of the partner, rather than past performance, or perceived capabilities (Lee & Moray, 1992).

In addition to Barber's dimension of trust, Muir (1989) incorporated Rempel et al. (1985) 's three dimensions of trust: predictability, dependability, and faith. According to Muir, these three dimensions of trust represent the dynamic nature of trust. As a result of changes in experience, trust develops in relationships. For example, predictability is a

foundation of the trust process in an early relationship. "Predictability" refers to the consistency and desirability of past behavior, and the predictability becomes the basis of the next stage, dependability. "Dependability" becomes the second basis of trust, and refers to an understanding of the stable characteristics of the partner's behavior. Faith is the final basis of trust and will be built based on the first two dimensions of trust, predictability and dependability. "Faith" is the belief in the extended behavior and must go beyond any available evidence. In a human-to-human relationship, it may take years to develop a relationship where a human partner understands the intentions of the other partner (Lee & Moray, 1992).

Table 1 is a matrix showing how each dimension described by Remple et al. (1985), Barber (1983), and Zuboff (1988) corresponds to each other in four different stages of trust. The four stages of trust are *foundation, performance, process,* and *purpose*. The first stage is the *foundation* of trust, representing the fundamental assumption of natural and social order that makes the other levels trust of possible. The second stage is *performance*. The *performance* stage focuses on the expectation of consistent, stable, and desirable performance or behavior. The third is *process*, which depends on an understanding of quality and characteristics of the systems and knowing how the system behaves. The final stage is *purpose*, which means, knowing the system designer's intention in creating the system (Lee & Moray, 1992).

Table 1

Proposed relationship between different dimensions of trust (Lee & Moray, 1992)

	Barber (1983)	Rempel, Holmes, and Zanna (1985)	Zuboff (1988)
Purpose	Fiduciary responsibility	Faith	Leap of faith
Process		Dependability	Understanding
Performance	Technically competent performance	Predictability	Trail-and-error experience
Fundation	Persistance of natural laws		

Rempel (1983) and Barber (1983) both include a very similar role to describe the *purpose* stage; faith and fiduciary responsibility correspond very closely to each other, and they are based on expectations of underlying motives and intentions (Lee & Moray, 1992). Predictability corresponds very closely to technically competent performance, and both cases depend on how stable and desirable the system is (Lee & Moray, 1992). The only difference is how much experience the operator has. A technically competent performance will be more experienced and knowledgeable about the machine.

Definitions of trust in new technology is described by Zuboff (1988) coincide with the dimensions of trust provided by Barber (1983) and Rempel et al. (1985). According to Zuboff, *trial-and-error* corresponds very closely to *predictability*. Both cases describe the expectations of how consistent and stable the machine is and determine the desirability of its performance or behavior. *Understanding* and *dependability* are very similar ideas. Both describe the expectation of future behavior through an understanding

of the partner's stable characteristics. *Faith* and *leap of faith* seem to be closely related. In the case of trust between human and machine, an operator may trust the machine without approved experience and evidence. The differences between *faith* and *leap of faith* will depend on the operators experience on the machine (Lee & Moray, 1992).

A Model of Trust and Reliance on Automation

Dzindolet, et al (2002) developed a model in Figure 1. It explains the framework of trust among humans and addresses the factors affecting trust and the role of trust in mediating reliance on automation. Trust and its effect on behavior depend on a dynamic interaction among the operator, context, automation, and interface. Trust also combines attitude with subjective workload, effort engaged, perceived risk, and self-confidence to form the intention to rely on the automation. There is an important decision involved in the operator's need to intervene or delegate the automation systems. Once the decision is made, factors such as time constraint and configuration errors may affect how much the operator actually relies on the automation. It is possible to say that the decision to rely on the automation depends on the type of the automation as well as the context. The operator's reliance on the automation may be influenced by environmental variability, such as weather conditions, and a history of inadequate maintenance. Those factors make reliance inappropriate (Lee & See, 2004).
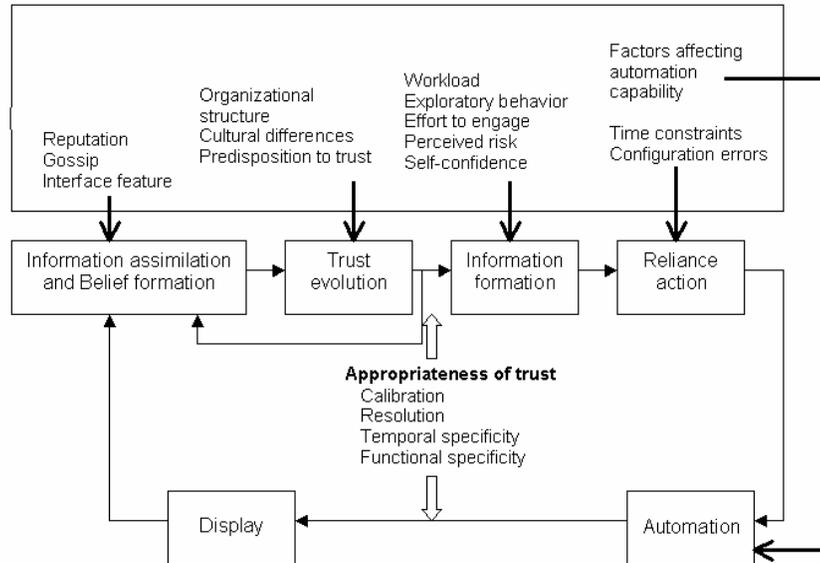
Figure 1. A Conceptual Model of the Dynamic Process that Governs Trust and its Effect on Reliance by Dzindolet et al. (2002)

Trust and Self-Confidence

Self-confidence is a critical factor in decision-making (Bandura, 1982; Gist & Mitchell, 1992). Self-confidence is a particularly important variable that interacts with trust to influence reliance. Just as operators' trust in automation may influence their reliance on automation; also too much self-confidence can influence their reliance on manual control. If the operators' self-confidence fails to correspond to their actual abilities, then they may allocate automation inappropriately, just as mistrust may lead to an inappropriate allocation strategy. Operators would become less likely to change allocation strategies and delegate control to automation. If operators consistently overestimate their capabilities, then they are likely to maintain manual control, failing to benefit from the capabilities of the automation (Moray & Lee, 1992).

Trust and Multitasking Demand Situations

In multi-tasking and demanding situations, the operators' trust can influence reliance. Generally people are not good at passive monitoring information for long periods of time (Endsley, Bolte & Jones, 2003). In a previous study of automation problems, 81% of reported problems in cruise were associated with not monitoring the systems (Moisier, Skitka, & Korte, 1994). When the operators have highly reliable automation combined with the responsibility for multiple tasks, in addition to monitoring the automation, this situation can lead to over-trust in automation and undermine the detection of automation failures (Parasuraman, Molly, & Singh, 1993). On the other hand, when the operators' only task was to monitor the automation, they detected failures effectively (Thackray & Touchstone, 1989).

Trust and Passive Tasks

According to Cownan (1988) and Slameck and Graf (1978), the very act of becoming passive in the processing of information may be inferior to active processing (Endsley, Bolté, & Jones, 2003, p. 178). It is almost impossible for a pilot to fully process or update the information which he/she is monitoring in working memory, though the information is appropriate (Endsley, Bolté, & Jones, 2003). For example, in the case which involved remembering how to get from point A to B by someone's driving, he would try hard to remember the direction if he knows that he has to drive back from B to A alone. Checking a computer manually, if it is adding correctly, is almost impossible without performing the calculation oneself. Therefore, monitoring and checking an automated system may be only partial attempts at a manual performance of the same task (Endsley, Bolté, & Jones, 2003).

A pilot who has high skills in the monitoring/scanning stage still has many chances to lose his/her second level of situational awareness which is comprehension of the situation due to the complexity of the automation systems. No matter how vigilant the pilot is, in some cases it is almost impossible to understand and interpret correctly what the automation systems are doing. Endsley, Bolté, and Jones (2003) states that compliancy or over-reliance on automation may not be directive cause of the out-of-the-loop syndrome, but a fundamental difficulty associated with full understanding what the system is doing when passively monitoring it.

To reduce over-trust in the automation, and to increase detection of failures, shifting between manual and automatic control, according to the capabilities of the person and the situation, is considered effective. In a previous study, participants monitored an automated engine status display while performing a tracking and fuel management task. This multi-task flight simulation included adaptive automation that shifted the engine status monitoring task to the person for 10 minutes in one condition. In another condition, the monitoring task was automated during the entire experiment. The result showed that the 10 minutes in manual control substantially improved subsequent detection of automation failures (Parasurman, Mouloua, & Molly, 1996). Passive tasks combined with the responsibility for other tasks seem to increase reliance on the automation.

Gaps between Expectations and Automation Behavior

A discrepancy between the operator's expectations and the behavior of the automation system can undermine trust even when the automation performs well (Rasmussen, Pejterson, & Goodstein, (1994). There is no single level of reliability that

can be identified that will lead to distrust and disuse. It is possible to determine that trust

depends on the timing, consequence, and expectations associated with failures of the

automation. The environmental context not only influences trust and reliance, but also

influences the performance of the automation. For example, the automation may perform

well in certain circumstances and not in others. Therefore, appropriateness of trust often

depends on how sensitive people are to the influence of the environment on the

performance of the automation. Trust is considered more than a simple reflection of the

performance of the automation. For example, appropriate trust depends on the operators'

understanding of how the context affects the capability of the automation (Lee & See,

2004).

<div align="center">*Appropriate Trust: Trust and System Capability*</div>

Inappropriate reliance associated with misuse and disuse may depend on how

well trust matches the true capabilities of the automation (Lee & See, 2004). Appropriate

trust is critical for appropriate system operation. Figure 2 indicates the matches and

mismatches between trust and capability of automation systems. *Calibration* indicates the

correspondence between a person's trust in the automation and the automation's

capabilities (Lee & Moray, 1994; Muir, 1987). In figure 2, the diagonal line represents

the good calibration. Above this line is over trust, and below it is distrust. There is good

calibration when the level of trust matches automation capabilities. *Overtrust* indicates

poor calibration when trust exceeds system capabilities. On the other hand, *distrust is*

indicated when trust falls short of the automation's capabilities. *Resolution* refers to how

precisely a judgment of trust differentiates levels of automation capability (Lee & See,

2004; Cohen et al., 1999). Figure 2 shows that poor resolution occurs when an operator's

trust level is very low with a large range of automation capability, when levels of trust

and system capability are not equal.

Good calibration and good resolution of trust can mitigate misuse and disuse of

automation (Lee & See 2004). Pilots also need to be able to adjust their knowledge

associated with system capability by experience. Systems' capability may change in

different circumstances such as time, weather, and maintenance; thus the pilots' trust and

their knowledge of system capability may need to be adjustable.
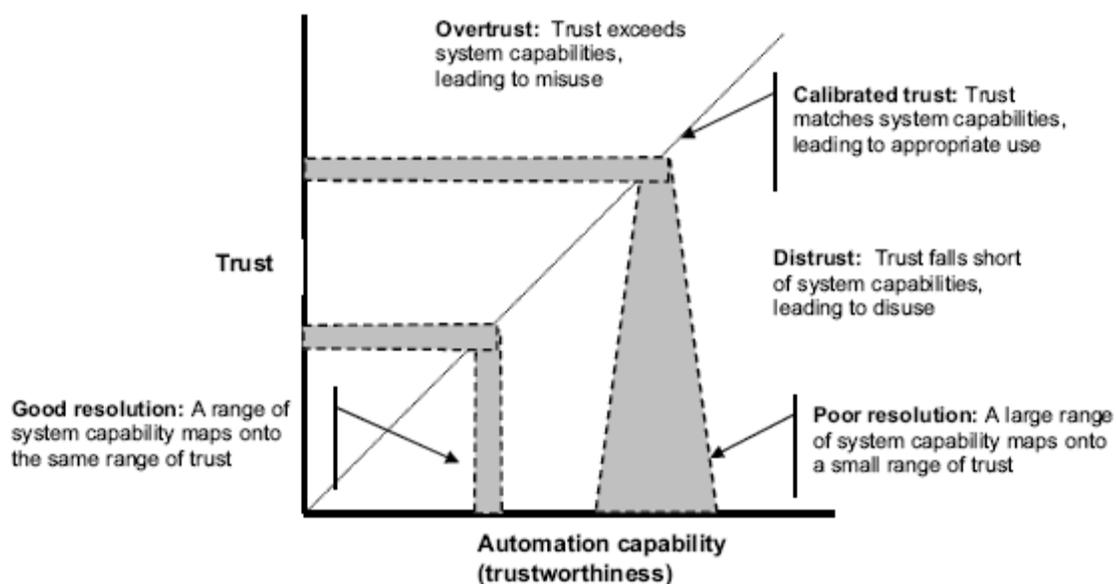
Figure2. Model of Appropriate Trust in Automation *(*The Relationship among
Calibration, Resolution, and Automation Capability in Defining by Lee & See, 2004)

Measurement of Trust between Human and Machine

In order to understand the concept of trust in automation systems, it is important

to measure trust effectively. Trust was studied mostly in the field of social psychology

(Jian, Bisantz, & Drury, 2000). Lazelere and Huston (1980) analyzed trust regarding

benevolence and honesty in partners. The researchers found several factors of trust

including such concepts as predictability, reliability, and dependability. Lazelere and Huston concluded that these factors may be dynamic, changing over time as relationships develop (Jian, Bisantz, & Drury, 200).

Lee and Moray (1994) and Muir and Moray (1996) examined operators' trust in automated systems in a simulated supervisory process control task. They then constructed a subjective rating scale to evaluate participants' perceptions of the reliability and trustworthiness of the automated systems. Only a few trust studies between human and automation systems have been done, and the questionnaires were based in part on those studies used in the social psychology research on trust (Jian, Bisantz, & Drury, 2000).

One assertion of the previous studies of trust is that trust is a multidimensional concept (Jian, Bisantz, & Drury, 2000 p. 54). The questionnaires in the previous studies differ in that some are designed to measure trust in a particular person or system, whereas others measure a more general propensity toward trusting (Jian, Bisantz, & Drury, 2000). For example, theoretical notions of trust in a romantic partner may be completely different from the trust between human and machine. Jian, Bisantz, and Drury (2000) argued that in previous research the questionnaires used to measure trust have included items based on different theoretical notions of trust, not based on an empirical analysis that attempts to understand multiple components of trust. Thus, in their study, they focused on trust between human and automation systems to evaluate how trust between humans and automated systems differed from trust between humans, or for that matter, from trust in general. Additionally, they attempted to identify potential similarities and differences among concepts of general trust, trust between people, and trust between humans and an automated system.

Their research concluded: (a) trust and distrust can be treated as opposites, and it is not necessary to differentiate between high and low levels of trust and high and low levels of distrust; (b) three types of trust, general trust, human- to -human trust, and human and machine trust, tended to be similar (it is unnecessary to measure them separately). Based on these two results, the researchers proposed and developed a scale for measuring trust between humans and machines.

The questionnaire developed by Jian, Bisantz, and Drury (2000) may be useful to investigate the relationships between pilots' trust and their performance in an aircraft. The questionnaire was created using word selections most related to trust. Results indicated that the three categories of trust were undistinguishable, having no significant bearing on data; hence, social-psychology-based questionnaires are still applicable to measure trust between humans and machines. The questionnaire was developed empirically to observe the differences across the three categories, and especially to measure trust between human and automation systems. Thus, in this paper the questionnaire of trust between human and automation uses an instrument that was produced by well- published authors in the field and has been used by others as a reliable measurement. Given the importance of trust, overtrust or undertrust in human interaction with technology, it is equally important but very difficult to measure trust. Wickens and Xu (2002) argue that trust is a psychological state and only be measured subjectively. There are multiple ratings scales for trust (Jian, Bisantz, Drury, 2000) and scales developed specifically for human interaction with computers (Muir and Moray, 1996). The point is that several rating scales have been developed. The tool used here was

selected because it had a precedent in the literature and was based on empirical data collected in the transportation industry.

<div align="center">Situational Awareness</div>

According to Ensley (1995), 88% of accidents among major airlines involving human errors could be attributed to problems with situational awareness as opposed to problems with decision-making or flight skills. The National Aeronautics and Space Administration (NASA) determined situational awareness as one of seven major task areas targeted for human error reduction in its Aviation Safety Program, in compliance with the government's goal of reducing fatal aircraft crashes by 80% over the next ten years (Huettner & Lewis, 1997). Reduction of accidents in general aviation may contribute substantially towards the overall goal of reducing aircraft accidents. Furthermore, focusing on improvement of situational awareness will contribute towards improving overall safety as these aircraft share the same congested airport areas, runways and en route environment with commercial aircraft (Endsley et al., 2000).

In a previous study of pilot-situational awareness, automation system related problems have been taken as good examples of commission and omission errors. For example, the flight management systems (FMSs) provide pilots with a considerable amount of flight path information. This flight path information includes the predicted path, the relative position of adjacent navigation aids, airports, adverse weather activity, as well as the location in space at which the intersection of a constant rate climb or descent reaches a predetermined altitude. As long as the operators are careful during course programming and setting, they can be confident that the performance of the navigation system will be accurate (Endsley & Strauch, 1997). The authors also argued

that the system can actually decrease pilots' awareness of parameters critical to flight

path control through the out-of-the-loop performance decrements, over-reliance on

automation, and poor human monitoring capabilities. Many studies show that in most

cases operators are unaware of automation failures and do not detect critical system state

changes when acting as monitors of automated systems (Ephrath & Young, 1981; Kessel

&Wickens, 1982; Wickens & Kessel, 1979; Young, 1969).

Achieving a satisfactory level of pilot-situational awareness is a critical and

challenging aspect in many industries (Endsley, 1996). It is also central to good decision

making and performance (Endsley & Strauch, 1997). According to Hartel, Smith, and

Prince (1991), poor situational awareness is a leading causal factor in military aviation

mishaps. In a recent commercial aviation review, 88% of human error-related problems

involved situational awareness issues (Endsley, 1995).

Situational awareness is formally defined 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 near future (Endsley, 1988 p.4)." Essentially,

situational awareness means that pilots need to be aware of what is happening around

them and understand what that information means to them now and in the future

(Endsley, et al., 2003). The automation systems and other aircraft operation systems such

as the instruments in traditional aircraft are great indications of what is happening inside

and outside of the aircraft; thus, effective monitoring of those systems is a critical task to

maintain high situational awareness.

As is depicted in Figure 1,there are three main levels of situational awareness:

perception of the elements in the environment (Level 1), comprehension of the current

situation (Level 2), and, at the highest level, projection of future status (Level 3) (Endsley, et all., 2003). For example, a pilot needs to recognize important elements such as other aircraft, weather, terrain, and system states, along with their relevant characteristics at Level 1 situational awareness (Endsley, 1997). In single pilot operation, keeping up with all the relevant system and flight data, other data and navigational data can be quite difficult to handle. Some pilots may lose their situational awareness in this stage. At Level 2 a pilot needs to be aware of the elements that are present and be able to understand the meaning of the critical factors (Endsley, 1997). At Level 3 situational awareness a pilot needs to be able to project what will happen at least in the very near future. This is achieved through both Level 1 and Level 2 (Endsley, 1997). It is important to maintain the balance of all the levels. This level of situational awareness is critical for decision makers to function in a timely and effective manner (Endsley, 1996).
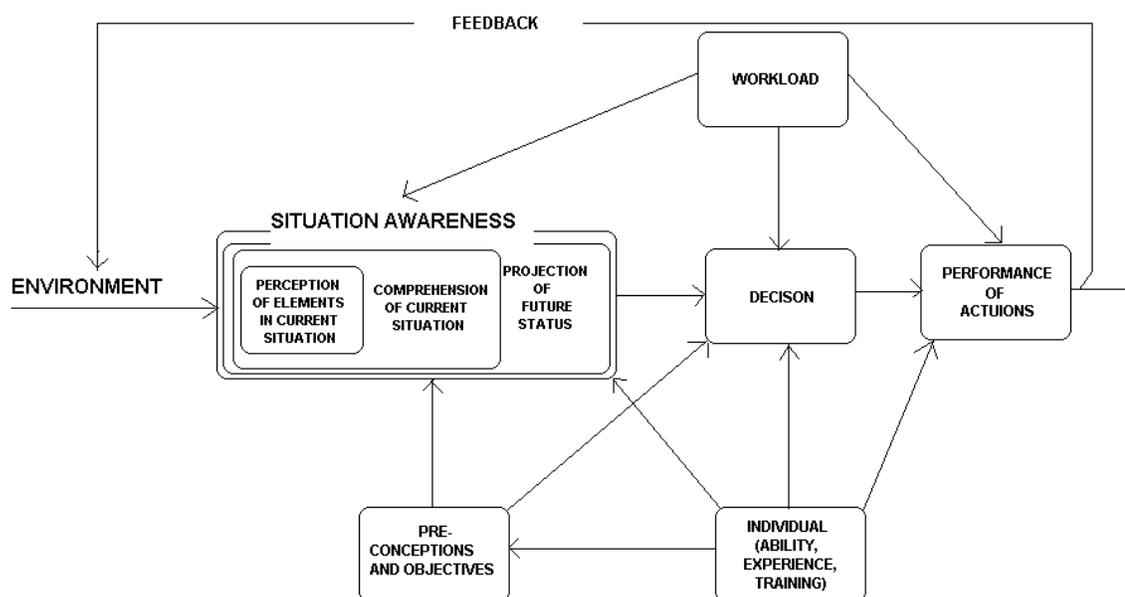

Figure3. Pilot Decision Making Model by Endsley (1990)

As part of single pilot resource management (SRM), it is critical for a single pilot to maintain Level 1 to respond effectively and efficiently in the next two levels of situational awareness. Pilots always have to be aware of what their on-board systems are doing, their own location and the location of important reference points and terrain, and the location of other aircraft along with relevant flight parameters and characteristics. It is essential to have good Level 1 situational awareness; however, much depends on how the pilots interpret the information they take in (Level 2). At Level 2, depending on how a pilot interprets, situations may be greatly changed. Pilots would be required to sense that a certain pattern of flight parameters indicates when they are near stall point or when the displayed altitude is below their assigned altitude (Endsley, 1996). At the highest level, Level 3 situational awareness, pilots comprehend the state of the system and predict its state in the near future. With accurate and complete situation awareness, pilots can use the systems effectively to meet their goals (Endsley, 1996).

Automation may directly impact a pilot's situation awareness through the following three major factors: changes in vigilance and complacency associated with monitoring, assumption of a passive instead of an active role in controlling the system, and changes in the quality or form of feedback provided to the human operator (Endsley & Kiris, 1995; Endsley, 1996). Each of these factors can lead to the out-of-the-loop performance problem.

Enemies of Situational Awareness

Good situational awareness is challenging due to features of both the human information processing system and of complex domains (Endsley, Bolté & Jones, 2003). The out-of the-loop syndrome could be the most critical factor. Automation systems help

pilots to eliminate excessive workload, but the systems also can act to lower situational awareness. The automation system complexity and mode errors, which can result when people mistakenly believe the system is in one mode when it is not, are situational awareness demons that relate to automation. In addition, automation can undermine situational awareness by taking people out-of-the-loop. In this state they develop poor situational awareness on both how the automation is performing and how the automation is supposed to be controlling (Endsley, Bolte & Jones, 2003).

Having bias on automation systems would be a critical obstacle to maintaining a high level of situational awareness. This bias may also lead the pilots to be out-of-the-loop. Human operators have a limited ability to detect automation failures or problems and to understand the state of the systems sufficiently to allow them to take over operations manually when needed (Endsley, Bolte & Jones, 2003).

Being out-of-the loop may not be a problem when the automation systems are performing properly; however, when the automation fails or, more frequently, reaches situational conditions it is not equipped to handle, the person is out of the loop and often unable to detect the problem, properly interpret the information presented, or intervene in a timely manner (Endsley, Bolte & Jones, 2003). People are often slow to detect a problem with an automated system (Ephrath & Young, 1981; Kessel & Wickens & Kessel, 1979; Young, 1969; Endsley, Bolte & Jones, 2003). In general aviation, pilots will expect flying with a moderate level of automation. Operators sometimes may decide to neglect the automated system, and the system parameters may be misunderstood by the automation in favor of other tasks through a shifting of attention (Parasurman, Mouloua, & Molloy, 1996; Endsley, 1996).

Single-pilot Resource Management

Single-pilot Resource Management (SRM) is one of the important FITS training program's criteria. FITS defines SRM as "the art and science of single pilot management of all the available resources to ensure that the successful outcome of the flight is never in doubt" (FAA/Industry Training Standards, 2004). Flying with fully automated aircraft might be helpful for a single pilot operation; however, automation fails from time to time. Furthermore, automation systems can decrease a pilot's situational awareness. As part of single resource management, pilots will be required to have a skill to manage all the resources inside and outside the cockpit. In order to carry out efficient and effective Level 2 and 3 situational awareness, a pilot must receive SRM training.

FITS's for SRM criteria includes primary emphasis on integrating the development and enhancement of the mental process and underlying thinking skills needed by the pilot to consistently determine the best course of action in response to a given set of circumstances (FAA/Industry Training Standards, 2004). Dealing with automated systems involves an operator's trust. Therefore, it is important to focus on the operator's mental processes in addition to developing their operation skills. Understanding and addressing pilots' mental processes to SRM training may be difficult, but it cannot be disregarded.

Aeronautical Decision-Making

Decision-making is one of the important cognitive tasks. Decision-making is considered as the act of choosing between alternatives under conditions of uncertainty (Tsang &Vidulich, 2003). Automation systems are introduced as aids to help pilots' cognitive tasks; however, the systems provide decision-makers with new guidelines or

shortcuts for decision-making and task performance (Mosier, Skitka, Heers, & Buradick, 1998). These systems lead to potential problems.

Pilots tend to relay upon probabilistic information to evaluate what they cannot access directly (Wickens & Flach, 1998). NASA Ames' experiment of automation bias (1989) found that automated cues can curtail information searches. During the take-off roll, crews received contradictory fire indication. An automated-sensing electronic checklist suggested shutting down the #1 engine which was supposedly on fire. However, traditional engine parameters indicated that the #1 engine quickly recovered and the #2 engine was actually more severely damaged. The result indicated that 75% of the crew in the automated condition shut down the #1 engine, and only 25 % who used the traditional paper checklist and non-automated aids did likewise. The study concluded that the crews in automated condition tended to discuss much less information before deciding whether to shut down the engine (Mosier, Skitka, Heers, & Burdick, 1998). Automation aids are greatly advanced; however, human operators still remain in control.

According to Endsley, Bolté and Jones (2003), situational awareness is the key factor driving the decision-making process. In complex and dynamic environments such as flying with automated systems, decision-making is highly dependent on situational awareness (Endsley, Bolté, & Jones, 2003). Automated aids change the way pilots perform tasks and make decisions (Mosier, Skitka, Heers, & Burdick, 1998), and lead pilots to create different levels of errors. Misuse and misinterpretation of the automation systems are still expected to occur in Technically Advanced Aircraft. These errors need to be evaluated and reduced.

Automation Cockpit

A significant difference between TAA and traditional aircraft is cockpit automation. While there are critical disadvantages of automation, automation is still essential for aviation safety. There are many advantages with automated aircraft. According to Wiener (1988), automation increased capacity and productivity, reducing of manual workload and fatigue, relief from routine operation, relief from small errors, more precise handling of routine operations, economical utilization of machines, and damping of individual differences.

According to Wiener (1988), cockpit automation seems a great boon to safety, removing human error at its source and replacing fallible humans with virtually unerring machines. On the other hand, the critics view automation as a threat to safety replacing intelligent human with devices that are both dumb and dutiful. This is a deadly combination. The digital systems seem to invite new forms of human error in their operation, often leading to gross blunders rather than the relatively minor errors which characterize traditional system. Furthermore, the equipment does not appear to live up to its expectations in reducing crew workload or increasing time available for extra-cockpit scanning (Curry, 1977; Wiener, 1985), since while the manual tasks may be declining, monitoring and mental workload have increased (Wiener, 1988).

Situation Awareness Global Assessment Technique (SAGAT)

Fracker (1991 a;b;c), Sarter and Woods (1994), and Vidulich (1992) classify measurement of situational awareness into the following categories; subjective, explicit, and implicit measures (Dennehy,1996). Subjective is one technique that has been used to ask pilots to rate their situational awareness on a Likert scale. Since they are not aware of

what is really happening in the environment, their ability to estimate their own situational awareness may not be effective. The pilots may think that they have perfect situational awareness until they encounter some problems (Endsley, 1988). Furthermore, when a pilot is asked to subjectively evaluate his/her situational awareness in a debriefing, his/her rating may tend to be positive. Because this information is gathered after the flight, the pilot will probably not be able to recall, and thus he/she will over generalize about his/her situational awareness (Nisbett & Wilson, 1977).

A detailed questionnaire could be administered after the completion of each run. The pilots may have enough time to respond to a lengthy and detailed list of questions. There are several disadvantages. People in general are not good at recalling past mental events, even recent ones. The best way to ask pilots to recall their accurate mental events is to ask the pilots about their situational awareness while they are flying. Furthermore, asking the pilots questions also giving them hints to the requested information on their displays, thus altering their true situational awareness (Endsley, 1988).

An implicit measure of situational awareness would assess the influence of specific events on performance (Fracker, 1991a). The goal is to determine whether pilots' mission performance has been influenced appropriately by the occurrence of specific events. Signal Detection Theory is one example to determine how people make decisions about uncertain events (Dennehy, 1996). In the present study, this technique is not applicable.

An explicit measure requires a pilot to report what he/she explicitly remembers in order that his/her situation awareness might be measured (Dennehy, 1996). An example of explicit concurrent measures is Situation Awareness Global Assessment Technique

(SAGAT) developed by Endsley (1987). SAGAT has achieved a high degree of validity and respect for specific military uses, for instance, in the air-to-air fighter cockpit. SAGAT measures a pilot's situational awareness in the following manner: a pilot flies a given mission scenario using a given aircraft system, during which, at a random time, the simulation is halted by a blinking light on the simulator display. The pilot is asked a series of questions in order to determine his or her knowledge of the current situation. The queries include all operator situational awareness requirements, including Level 1 (perception of data), Level 2 (comprehensions of meaning), and Level 3 (projection of the near future) components. Their answers are evaluated on the basis of what was actually happening in the simulation. Then the score is typically stratified into three zones- immediate, intermediate, and long range, in order to provide a better picture of pilots' situation awareness (Endsley, 1988).

The SAGAT enables situational awareness evaluators to: (a) provide a current "snapshot" of the pilot's mental model of the situation, thus reducing the effects of collecting data after the event; (b) directly measure the pilot's knowledge of the situation, his situational awareness; (c) objectively collect and, for the most part, objectively evaluate and (d) possess direct face validity (Endsley, 1988).

The primary limitation of SAGAT is that the simulation needs to be halted to collect the data. Sarter and Woods (1991; 1994) suggest that this methodology does not provide data about natural character and occurrence of situational awareness (Dennehy, 1998).

In this study, SAGAT is used during real time flight. Embry-Riddle Aeronautical University (ERAU) novice pilots' instructors conducted the SAGAT interview during a

flight. Instead of halting the flight at a certain point, the instructors took a moment to ask their students, using provided situational awareness in the questions middle of the flight, typical situational awareness questions generated by a subject matter expert. This technique allows data collection in actual flight training situation without alerting the participants that their situational awareness is going to be evaluated.

Since the researcher anticipate that novice pilots who have higher levels of trust will not be paying as much attention to their instruments as persons with less trust, the researcher expect the higher the trust the lower the situational awareness (SAGAT) score. If a pilot is over-reliant on a particular system, his or her situational awareness may suffer; vice versa, a lack of trust (distrust) may cause him or her to disregard information critical to his or her situational awareness.

<div align="center">Hypothesis</div>

It is hypothesized that: (a) pilots who have high scores on the trust scale will have low situational awareness during the flight; (b) pilots who have low scores on the trust scale will have high situational awareness.

CHAPTER III

RESEARCH METHODOLOGY

Research Techniques

The first procedure of the experiment was to determine the shape of the sampling distribution as a result of the Jian (et al., 2000)'s original and modified vision of trust scale among ERAU pilots, student pilots and non-pilots. In Jian's modified version trust scale, high and low trust scores were determined among the ERAU pilots and student pilots for Study II (Study I). The second procedure of the study was to calculate a trust score from a subsequent group of pilots and student pilots and to compare those scores with their situational awareness score during a simulated flight exercise (Study II). Non-parametric statistical evaluations of the results were used to determine the relationship between the trust score of participants and their corresponding instructor based situational awareness score.

Study I: Jian's Trust Survey

Participants

A total of 150 ERAU students who were attending the Spring Semester (2006), including 47 students from Human Factors classes and another 103 students from the Aeronautical Science (AS) 132 Basic Aeronautics I, 133 Basic Aeronautics II, 232 Intermediate Aeronautics, and 272 Advanced Aeronautics participated in the Jian's original questionnaire. The 150 students could be further distinguished into 111 pilots (with more than 35 total flight hours) and 32 student pilots (less than 31 total flight hours), and seven non-pilots (had zero flight hours).

Then, the modified trust survey tested 88 pilots and student pilots who were attending AS133, AS 232, and AS 272 during the summer semester (2006). The researcher used student pilots from the private certificate course (AS 133), pilots from the instrument rating course (AS 232) and the commercial rating course (AS 272) in order to have a chance to use the same candidates for the Flight Training Device (FTD) testing later. They participated in this questionnaire type survey that measured participants' trust level using the edited trust scale.

Procedures

The original trust scales developed by Jian, Bisantz, & Drury (2000) was used to survey the ERAU students including pilots and student pilots' trust levels. This scale was selected because it was one of only two studies found which formulated a trust score based on empirical data and the only one to have been used by other researchers. The Jian's trust scale is a seven-point Likert scaled questionnaire, with higher scores corresponding to higher trust levels, and lower scores corresponding to lower levels of trust. A copy of the Jian's scale is included in Appendix A1. Due to complaints from participants in the Jian's original trust survey some of the wording on this questionnaire was changed. Hopefully, the meaning of the questions was unaltered. The modified version is included in Appendix A2 for comparison. It can be seen that questions 1-5 in both versions asked the pilots what might be considered negative questions, questions that are phrased in the negative. These were designated "Worrisome" questions. Questions 6-12 asked the pilots their feelings about technological systems in what were considered a positive manner, so were considered "Non-Worrisome questions".

The researcher and the professors who were teaching AS132, AS133, and AS 232 handed out the survey, and gave a brief statement describing the purpose of the survey before their class period began. They were then asked to complete their survey anonymously and return it to the investigator in the back of the room. Most surveys took approximately three minutes to complete. These were scored by hand using the technique described in Jian (et al., 2000) and analyzed using SPSS statistical evaluation software (ver.12).

Study II: Evaluation of Trust survey and Situational Awareness

Participants

A total of 30 participants including ten student pilots working on their single/multi private certificates (FA 133S/M), 15 pilots working on their single/multi engine instrument (FA 195D/232), and five pilots working on their commercial ratings (FA 272), assigned for a dual flight session (instructor accompanied flight) in the FTD simulator, were selected from the list of those entering the FTD for training. They were asked to sign the volunteer sheet, and were further separated into categories. The participants in this experiment received the FTD flight portion of their regular pilot training curriculum in a Frasca Cessna-172 aircraft fixed-base Flight Training Device (FTD) located in ERAU's Center for Advanced Simulation. The pilots and student pilots were asked to volunteer for Study II by signing a list before their FTD flight began. Their flight instructors were asked, during the lesson, to rate the participants for their situational awareness during one of their required flight modules in the FTD. Neither instructors nor pilots/student pilots were remunerated for their participation and they were never asked to do anything during their flight training that would be considered

unusual for their flight training. For the SAGAT scores, a subject matter expert familiar with SAGAT procedures was enlisted to come up with questions for the FTD flight module that were considered to be consistent with the participants' flight training and consistent with good situational awareness. These questions are listed in Appendix B. The trust data were compared with the participants' situational awareness scores to determine the strength of the relationship between the participants' trust levels and their level of situational awareness.

<center>*Materials*</center>

The subject matter expert, a professor from Aeronautical Science Department, developed the situational awareness evaluation questions based on ERAU's FTD module 39, electrical failure in departure phase and the FTD module 221, and engine failure for multi engine. The electrical failure exercise was considered as the most suitable to evaluate the relationships between the participants' situational awareness and their reliance on the instrument panels since the responses showed the most variability in response. Engine failure exercise also is a common exercise in the FTD, so the engine failure scenario was also used to evaluate situational awareness.

In order to meet the convenience of the instructors and to fit into the one hour of FTD training paid for by the participants, there were only six situational awareness questions developed. As is typical of the SAGAT method of assessment of situational awareness, there were three types or levels of questions: perception (Level 1), comprehension (Level 2), and projection (Level 3). There were two questions for each level and the format used by the instructor pilot who delivered the questions is shown in the form on Appendix 3. The first question was 'how long will battery power last'?

(Level 1). Do you need to load-shed (Level 1)?; where are you on the departure procedures (Level 2)?; do you call ATC and advise of the failure (Level 2?); what systems are affected by an electrical system failure (Level 3)?; and how will performance data be affected (Level 3)?. The engine failure scenario has also two questions in each level and totals six questions: did you follow all steps in appropriate checklist (Level 1)?; how did you compensate for rudder (Level 1)?; what is happening aerodynamically to aircraft on one engine (Level 2)?; What are aircraft limitations on one engine (Level 2)?; What are things to consider when landing with one engine inoperative (Level 3)?; and in current flight conditions, where would you elect to land (Level 3)?

Procedures

The participants who were working on their single/multi engine private (FA 133S/M), single/multi engine instrument (FA 195D/232), and commercial ratings (FA 272), and assigned for a dual flight session (instructor accompanied flight) in the FTD simulator were selected from the list of those who were entering the FTD for training and asked to sign the volunteer sheet. Their instructors automatically became their situational awareness evaluators. Before their FTD training, the participants were asked to fill out the trust questionnaire to determine the participants' trust levels.

The flight instructors (the evaluators) were given the situational awareness evaluation sheet with an instruction in order to conduct the SAGAT procedure. Typically, the same flight instructor had multiple students who volunteered so SAGAT training was needed only once. They were told their data will be kept confidential and anonymous by the project investigator. The instructors conducted the SAGAT during the training; at a certain point, the instructors posed the six situational awareness questions. The

participants were not given any hints from the instrument panel, Pilot Operation Manual, Pilot Operation Handbook, check-list, or their instructors. The instructors evaluated the participants' answers as either correct or incorrect. The Electrical failure scenario was successfully collected from 23 participants while only six evaluations of engine failure scenarios were collected. Of the 30 participants one did not complete their questioner, thus his or her data was excluded.

CHAPTER IV

RESULTS

Study I: Jian's Trust Survey

The descriptive statistics results from Jian's original trust survey (Appendix A1) are indicated in table 2. Figure 4 was visually analyzed to determine the shape of the distribution and to give the project investigator experience with the trust scale and interpreting the numbers. The trust score associated with the upper 20 % of the distribution (~78) and that for the lower 20% of the distribution (~52) were used to set the high and low trust scores, respectively in Study II.

Some of the questions were reworded in the original questionnaire because of complaints from participants in Study I. Every effort was made to keep the meaning of the few questions that were changed (Appendix A2) while making the question clearer. The descriptive statistics results from Jian's modified trust survey are indicated in table 3. Figure 5 shows the distribution from the 85 participants who participated in Jian's modified trust survey in Study I. The data from these 85 participants were used to determine the high and low trust scores. Figure 5 was also visually analyzed to determine the shape of the distribution, to interpret the numbers, and to make sure that the distributions between the data from original and modified trust scales were not completely different. The trust score associated with the upper 20 % of the distribution (~75) and that for the lower 20% of the distribution (~45) were used to set the high and low trust scores, respectively in Study II.

Table 2

Results of Jian's Original Trust Scale

		VFR	IFR	Glass	Trust Score
N	Valid	150	150	150	141
	Missing	0	0	0	9
Mean		92.23	13.99	5.98	65.57
Median		80.00	1.00	.00	67.00
Std. Deviation		92.637	30.813	41.893	10.301

Table 3

Results of Jian's Modified Trust Scale

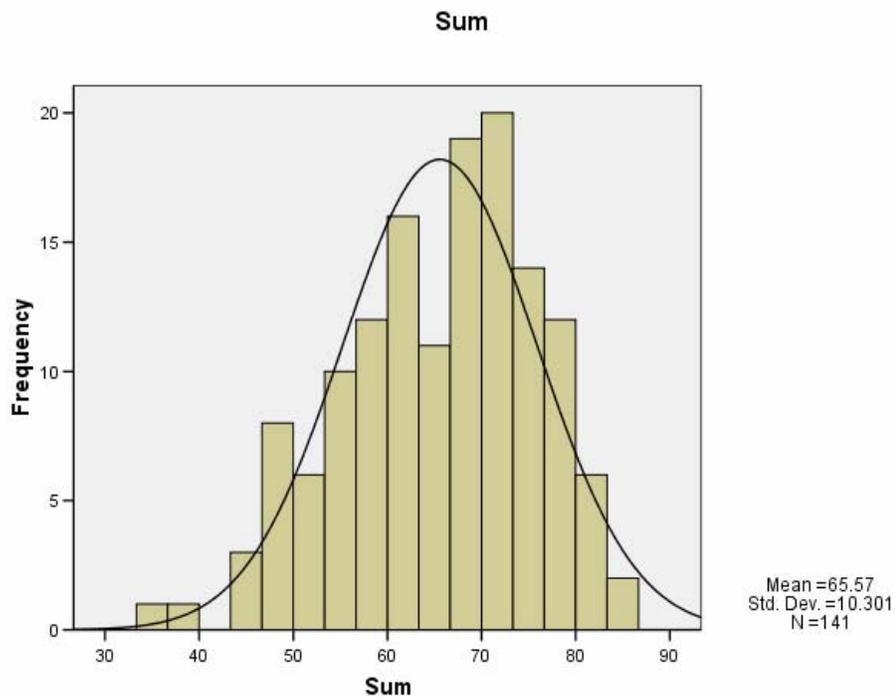|		VFR	IFR	Glass	Trust Score
N	Valid	77	77	77	85
	Missing	8	8	8	0
Mean		78.14	15.61	2.35	60.57
Median		60.00	.000	.00	60.00
Std. Deviation		68.10	31.55	7.76	12.24

Figure 4. Histogram of Original Trust Survey Results for Study I (Pilots and non-pilots were not different so were combined. Trust score is on the X axis)
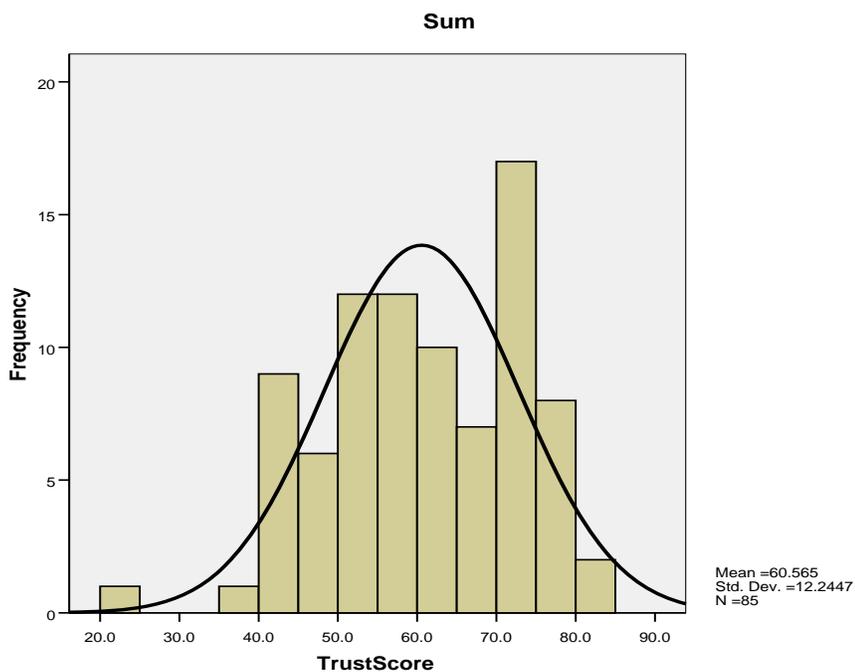

Figure 5. Histogram of Modified Trust Survey Results for Study I

Study II: Evaluation of Trust and Situational Awareness

Trust scale and their flight experience

There were 30 participants who were used in the Study II analysis. Only 19 participants of these 30 provided their VFR, IFR and Glass cockpit flight experience hours. The mean VFR flight hours was $M = 98.05$, IFR hours' mean was $M = 15$ hours, and the glass cockpit experience hours' mean was $M = 0.26$ hours.

Situational Awareness Evaluation

There were six participants evaluated using the engine failure scenario, while 23 participants were evaluated using the electric failure scenario for situational awareness. A Mann-Whitney Test was conducted to determine if there were any significant differences between the two different situational awareness scenarios. Each level of the situational awareness scores was graded to determine the number of correct answers of the two questions at each level. If a participant had two correct answers out of two questions, they were scored two. The scores from each level were added in the end (max is 6) to get the totals used in the statistical analysis. Six participants' data were randomly selected, through the use of a random number generator, from the 23 Electrical failure scenarios to equalize the number of the participants who used the engine failure scenario.

The test statistics show that the two different scenarios had no significant differences (U= 12; p<0.138). Thus the data from the two different scenarios were combined, and analyzed to observe further correlations.

Figure 4 shows the total situational awareness and trust among three different groups, private, instrument, and commercial ratings. As the pilots go upper levels ratings, trust levels seemed be higher.

SA Compareson among different classes
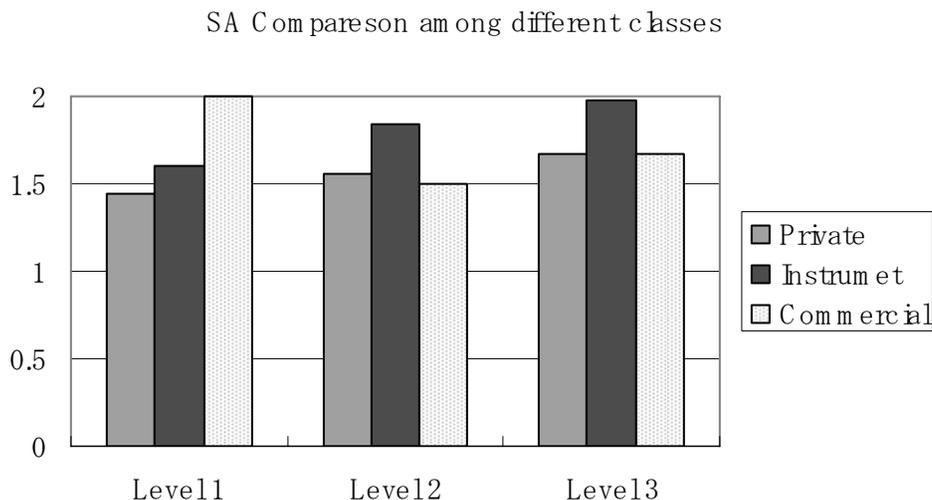
Figure 6. Histogram of Situational Awareness Scores (for each of the 3 SA levels (x axis) for the participants in Study II)

Kruskal-Wallis Tests were run to determine if differences existed among the many classes from which participants were drawn for the study (FA 133, 232, 295 and 272) in the three different SA levels. There were eight participants in FA 133 private pilot rating class, five participants in FA 233 multi-engine instrument rating class, and ten participants in FA 295 the single-engine instrument rating class, and six participants in FA 272 the commercial rating. Figure 6 shows that in Level 1 (perception), those FA 272 participants who were working on multi-engine commercial ratings performed better than the other flight ratings (private or instrument) using a Kruskal-Wallis test ($p < 0.039$).

Trust vs. Situational Awareness

In order to investigate the relationships between the participants' situational awareness and their trust levels, ordinal regression analysis also was conducted. This regression model was not significant ($p < 0.31$) so there does not seem to be a good fit for overall trust related to overall situational awareness scores. However, in examining the

ordinal regression table of parameter estimates, it was noticed that there were several

significant results between the high and low trust scores and situational awareness scores.

When the trust scores were low (35-45 range), significance levels were less than 0.01 and

strongly correlated to situational awareness scores. The two highest trust scores (81 and

82) also showed a strong relationship to situational awareness scores ($p<0.01$). These data

are suggested by the graph in Figure 7.
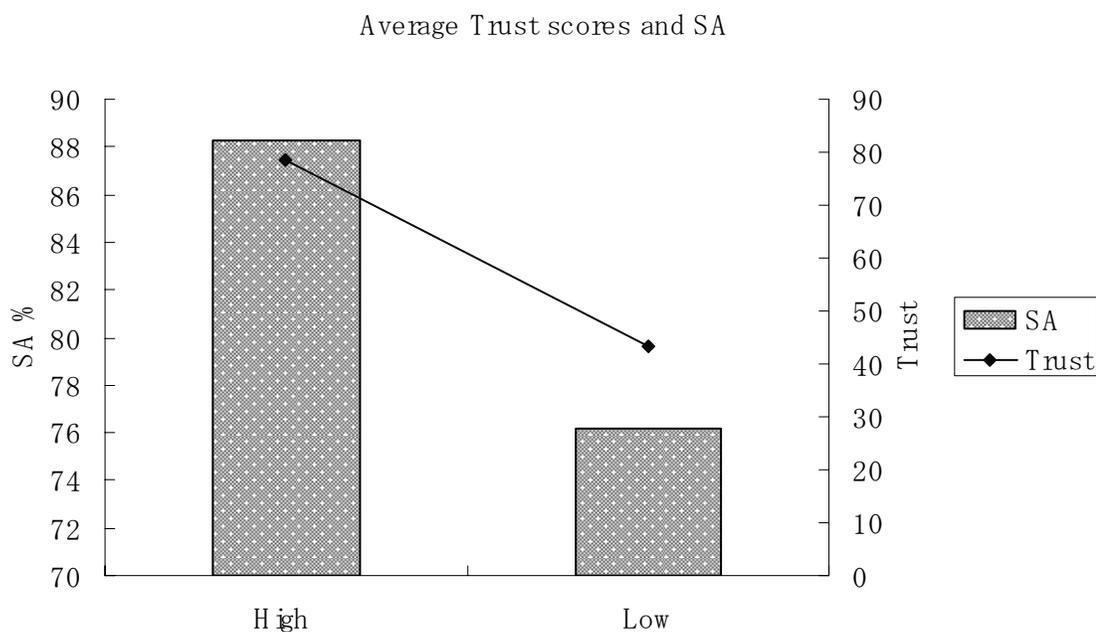
*Figure 7. Average Trust vs. SA (A high SA score is associated with a high trust score.
Conversely, a low SA score is associated with a low trust score)*

CHAPTER V

DISCUSSIONS

This study was conducted to evaluate the relationship between trust and situational awareness in novice pilots. The results of relating situational awareness to trust level did not support the original hypothesis at first. It was expected that high-trust pilots would have lower situational awareness, and low-trust pilots would have higher situational awareness. Instead, the reverse was found, high-trust pilots actually had higher situational awareness and low-trust pilots had lower situational awareness. The original hypothesis was based on the concept that existed in the literature. Novice operators tended to put too much reliance on technology. Since novice pilots are using many new instruments they may experience the bias to trust their equipment unquestioningly. It was felt that the untrusting pilot would need to continually update their situational awareness and examine many instruments; hence have a better overall situational awareness. The trusting pilot might be more inclined to pay less attention to instruments if they were perceived as reliable and unfailing and hence not pay as much attention to their situational awareness. That this was not the case suggests to the author that the high trust pilots were not blindly trusting their instruments but using them to establish a good situational awareness. The low trust pilots in this new view could be under scrutinizing their equipment and hence experience a low situational awareness. These results suggest the EARU novice pilots did not blindingly trust their instruments, but rather they trusted them intelligently. In other words, the pilots tended to know in detail about their aircraft systems and had reason to trust them. Similar findings exist in the medical realm (Wiegmann, et al, 2001) in which subjective assessment of trust and error rate were

related with personnel who tended to trust their equipment more were nonetheless sensitive to the information reliability.

There were three main stages to this study. The first two stages studied the application of the Jian's trust scale, the original and the edited version, to understand the dynamics of the distribution of trust as measured by the scale and to determine how to identify high-trust and low-trust pilots. The third stage was to apply the trust scale of pilots' to their situational awareness levels. The two different scenarios, the electrical and the engine failure scenarios, were used to evaluate situational awareness.

The original trust scale developed by Jian, Bisantz, & Drury, (2000) was used to generalize the idea of the participants' trust. However, the participants' response was not effective, and many participants reported that the questions were difficult to understand. Thus, the original trust scale's wording was changed slightly.

Finally the trust data and the situational awareness scores from 29 pilots and student pilots were compared. First of all the Kruskal- Wallis test was run to observe if there were significant differences in situational awareness levels among the three different groups: private, instrument, and commercial ratings. SA level 1 showed significance for the more experienced commercial pilots. The student pilots who were working on their private certificates had the lowest rank among the other two ratings, instrument and commercial ratings. Over all, the pilots who were working on their instrument rating and above had better situational awareness.

An Ordinal Regression analysis revealed the unexpected finding that high-trust scores yielded higher situational awareness and low-trust scores yielded lower situation awareness.

Not only the results suggested that the ERAU pilots tended to know in detail about their aircraft systems and had reason to trust them, but also possibly indicate that the novice pilots had an effective balance between the levels of trust and self-confidence, which in turn, may moderate their reliance on the systems. Novice pilots may be taught rather to trust the instruments than trust their sense of balance in their trainings. They tend to follow the books and perform as they were trained. Thus, this experiment may have found that high trusting pilots have better situational awareness. On the other hand, experienced pilots may have tendency of gaining confidence in their judgment or the systems. This kind of confidence could either lead to overconfidence in the systems or themselves. Overconfidence in the systems could lead to over-reliance on the systems: the operators will have low situational awareness. Overconfidence in the operators themselves could lead to distrust in the systems, and tend to operate manually: the operators will have high situational awareness.

The trust scale seemed to be effective in measuring a psychological concept that might be called "trust" in technology. Trust scores, especially high scores, may indicate that the participants have good situational awareness. Alternatively, lower or middle trust scores may demonstrate that pilots need to improve their situational awareness.

While the SAGAT procedure is a great tool to measure pilots' real time situational awareness, the trust scale could be beneficial to measure pilots' potential situational awareness attitude on the ground. There are possibilities to encounter rare situations, extreme conditions when pilots' situational awareness is evaluated in real time. In that case, their potential attitude towards their equipments may possibly be hidden somewhere. Though pilots' situational awareness is strongly influenced by

situations and their physical/mental conditions at the certain moment, their potential situational awareness attitude should be stable. Thus, investigation of pilots' situational awareness attitude should not be ignored to improve the pilots' self awareness and system evaluation.

Finally, the novice pilots who volunteered in this study may not have been effective. Though the research results had interesting results among the three different ratings, their piloting skills could be unstable and immature. Their trust levels may be also unstable because their piloting skills and knowledge are still developing. Perhaps different results would be obtained with more experienced pilots.

From these results, it may be possible to measure pilots' trust in automated aircraft by investigating "human out of the loop syndrome;" and distinguish between pilots' situational awareness and reliance. The Cessna 172 in the FTD was equipped with the traditional "six-pack", and the pilots were practicing manual flight in the FTD. Pilots trusting in everything (not only automation systems but also traditional instrument, check-list, ATC, etc) could also influence their situational awareness. However, reliance levels on the automation systems may be greater than reliance levels on any other traditional instruments or navigation systems because automation systems such as auto-pilot, GPS, FMS, etc may easily lead to a pilot out-of-the-loop syndrome.

The interesting results may support the use of a ground based questionnaire to evaluate trust in pilots. Low trusting pilots could be advised that they needed to scrutinize and trust their equipment better in order to increase their situational awareness. Pilots who rated low on the trust dimension might need more encouragement to make better use of their reading of instruments. Other high technology occupations could benefit from a

tool that can accurately assess trust. Overtrusters and undertrusters can be advised accordingly. It is recommended that additional funding be made available to allow the pursuit of the positive results of this study and develop a trust assessment tool that is geared towards the pilot and aviation. The results of this study argue that such a tool might have important use in identifying which pilot or pilot student needs to learn more about their instruments in order to incorporate the new technology into their overall situational assessment.

CHAPTER VI

CONCLUSIONS

In conclusion, this research has revealed that novice pilots' trust and their situational awareness are correlated. The pilots who had high trust scores seemed to have high situational awareness of their flight surroundings. Alternatively lower or middle trust scoring pilots may need to improve their situational awareness by putting more reliance on their instruments.

With regards to automation, the view of many authors cited in this work bears repeating that advanced computer systems, particularly for systems where overconfidence or overtrust or overreliance could be involved, need to have a means to indicate system failure to alert the operator that the information is no longer valid. Guidelines have been developed that can lead to identifying which systems should be automated and to what extent to improve the interaction of humans with machines, of pilots with technically advanced aircraft for example (Parasuraman, Sheridan, Wickens, 2000). The usefulness of alerting pilots to failed or incorrect instruments is evident in studies that show pilots quickly notice failed instrument cues and learn to find other means to get the information they need, particularly in high workload environments (Xu, Wiceksn and Rantanen, 2005).

CHAPTER VII

RECOMMENDATIONS

This study revealed that ground based trust measurements were able to predict a pilots' situational awareness in flight, at the extremes of high and low trust. Therefore the Jian's trust scale might be an effective and convenient tool to predict pilots' situational awareness behavior before flight training. Trust scores, especially high scores, may indicate that the participants have good situational awareness. Alternatively lower or middle trust scores may need to improve their situational awareness. This researcher recommends that not only a trust scale be used to assess pilots' situational awareness early on in training, but also during the training and periodically after the pilots receive the license. That method may help the observation of how the pilots' trust level is shifting and investigating how the pilots' experience affects their trust level. Further study of trust will help establish a more effective prediction.

Trust needs further investigation. Investigating how trust impacts situational awareness may be useful in this approach. For example, pilots' self-confidence and their complacency might influence trust appreciably. Approaching the trust investigation from those dimensions may help improve the trust scale. Many researchers determined trust as a willingness, behavior, and attitude that leads to an action of reliance. However, the components that make up trust or reliance are still not clear. There is a strong possibility self-confidence is influencing trust. Delegation is also a very interesting component which may influence the reliance action.

In order to enhance human and aircraft operations, evaluation of situational awareness training also is important. Approaching the evaluation of situational awareness

from an understanding of the role of trust seems fundamental. This type of approach is not common, but as this study's results indicate, there may be a significant relationship between trust and situational awareness.

In this study, situational awareness was measured in the FTD. The researcher presumes that these results will generalize to actual aircraft operation. Still, it would be beneficial to extend these results to actual aircraft flight. Many of the same methods outlined here could be employed. This researcher further recommends continued study in virtual flight and comparisons with actual flight to determine what, if any differences might exist. Many researchers indicated trust will have a greater influencing effect when a pilot is dealing with automation. The study of trust in automation aircraft would produce clearer results.

This study also has implications for the FITS program. Novice pilots using advanced technology will make better use of that equipment if they trust it. This study argues that the use of high technology in aircraft will be successful in increasing the situational awareness of the novice pilot. It is recommended that novice pilots using glass instruments be assessed in their trust levels in order to gauge their likely situational awareness early in their training.

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APPENDICES

APPENDIX A

Jian's Trust Scale

APPENDIX A1

ORIGINAL TRUST SCALE

· PLEASE DON'T FILL IN YOUR NAME, JUST YOUR HOURS FOR THE CATEGORIES BELOW

If you are a non pilot please put 0 (zero) in the hours categories below.

VFR hours _____   IFR hours _____   Glass hours _____

Glass refers to PFD, MFD computerized display

Please *circle the number* on each line at the point which best describes your feeling or your impression. For the purpose of this survey, "system" refers to the aircraft's systems, for example, the instruments, navigation system, autopilot, etc and what they tell you as a pilot. IF YOU ARE A NON-PILOT, please consider that 'system' refers to an automobile, i.e. what all the gauges and steering tell you as a driver.

PLEASE ANSWER AS CANDIDLY AS YOU CAN.   (Note: not at all = 1: extremely = 7)

1 The system is deceptive

```
1       2       3       4       5       6       7
```

2 The system behaves in an underhanded manner

```
1       2       3       4       5       6       7
```

3 I am suspicious of the system's intent, action, or outputs

```
1       2       3       4       5       6       7
```

4 I am wary of the system

```
1       2       3       4       5       6       7
```

5 The system's action will have a harmful or injurious outcome

```
1       2       3       4       5       6       7
```

6 I am confident in the system

```
1       2       3       4       5       6       7
```

7 The system provides security

```
1       2       3       4       5       6       7
```

8 The system has integrity

```
1       2       3       4       5       6       7
```

9 The system is dependable

```
1       2       3       4       5       6       7
```

10 The system is reliable

```
1       2       3       4       5       6       7
```

11 I can trust the system

```
1       2       3       4       5       6       7
```

12 I am familiar with the system

```
1       2       3       4       5       6       7
```

Thank you for your participation!!

APPENDIX A2
MODIFIED TRUST SCALE

Name: _____   E-mail _____

If you are a non pilot please put 0 (zero) in the hours categories below.

VFR hours _____   IFR hours _____   Glass hours _____

Glass refers to PFD, MFD computerized displays

Please **mark the number on each line** at the point which best describes your feeling or your impression. For the purpose of this survey, "system" refers to the aircraft's systems, for example, the instruments, navigation system, autopilot, etc and what they tell you as a pilot. IF YOU ARE A NON-PILOT, please consider that 'system' refers to an automobile, i.e. what all the gauges and steering tell you as a driver.
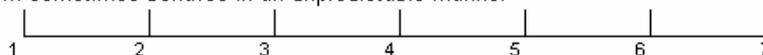
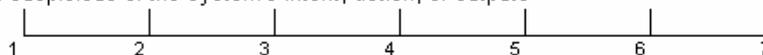PLEASE ANSWER AS CANDIDLY AS YOU CAN.   (Note: not at all = 1: extremely =7)
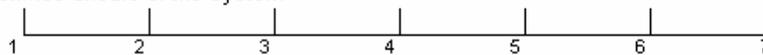
1 The system can be deceptive

1   2   3   4   5   6   7
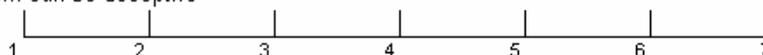
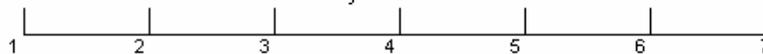2 The system sometimes behaves in an unpredictable manner

1   2   3   4   5   6   7

3 I am often suspicious of the system's intent, action, or outputs

1   2   3   4   5   6   7

4 I am sometimes unsure of the system

1   2   3   4   5   6   7

5 The system's action can have a harmful or injurious outcome

1   2   3   4   5   6   7

6 I am confident in the system

1   2   3   4   5   6   7

7 The system can provide security

1   2   3   4   5   6   7

8 The system has integrity

1   2   3   4   5   6   7

9 The system is dependable

1   2   3   4   5   6   7
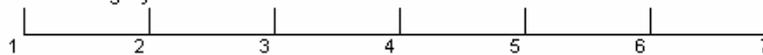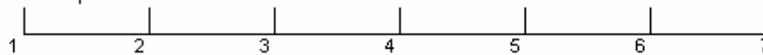
10 The system is consistant
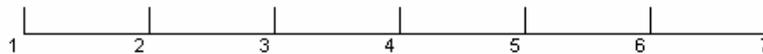
1   2   3   4   5   6   7

11 I can trust the system

1   2   3   4   5   6   7

12 I am familiar with the system

1   2   3   4   5   6   7
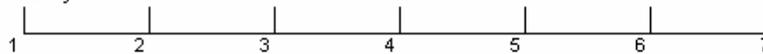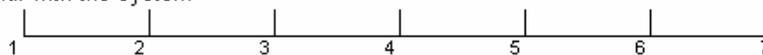
Thank you for your participation!!

APPENDIX B

Situational Awareness Evaluation Sheets

APPENDIX B1

Situational Awareness Evaluation Sheet

Electrical Failure (Departure Phase)

Instructor's name _____   Date _____

Student's name _____   Lesson _____

Please evaluate your student's Situational Awareness (SA). To assess SA, the simulator is typically frozen for a few minutes and the student looks away from the instruments. You may ask those questions in different order, but do not give your student any hints. The questions are correct or incorrect. When you finish filling out this sheet, please put it in the box on the front desk.
This study is approved by Ivan Grau. Your name and data will be kept confidential.

1. How long will battery power last? (Level 1)

                                                                Correct   Incorrect

2. Do you need to load-shed? (Level 1)

                                                                Correct   Incorrect

3. Where are you on the departure procedures? (Level 2)

                                                                Correct   Incorrect

4. Do you call ATC and advise of the failure? (Level 2)

                                                                Correct   Incorrect

5. What systems are affected by an electrical system failure? (Level 3)

                                                                Correct   Incorrect

6. How will performance data be affected? (Level 3)

                                                                Correct   Incorrect

Thank you,

Yoko Kunii

Master of Science in Aeronautics

APPENDIX B2

Situational Awareness Evaluation Sheet

Engine Failure

Instructor's name _____   Data _____

Student's name _____   Lesson _____

Please evaluate your student's Situational Awareness (SA). To assess SA, the simulator is typically frozen for a few minutes and the student looks away from the instruments. You may ask those questions in different order, but do not give your student any hints. The questions are correct or incorrect. When you finish filling out this sheet, please put it in the box on the front desk.
This study is approved by Ivan Grau. Your name and data will be kept confidential.

2. Did you follow all steps in appropriate checklist? (Level 1)

                                        Correct   Incorrect

3. How did you compensate for rudder? Foot pressure or rudder trim or combo? (Level 1)

                                        Correct   Incorrect

4. What are aircraft limitations on one engine? (Level 2)

                                        Correct   Incorrect

5. What is happening aerodynamically to aircraft on one engine? (Level 2)

                                        Correct   Incorrect

6. What are things to consider when landing with one engine inoperative? (Level 3)

                                        Correct   Incorrect

7. In current flight conditions, where would you elect to land? Or would you continue flying? (Level 3)

                                        Correct   Incorrect

                                    Thank you,
                                    Yoko Kunii
                                    Master of Science in Aeronautics