Spring 2008

The Influence of Motivation and Investment on the Length of Time Pilots Fly into Degraded Weather

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THE INFLUENCE OF MOTIVATION AND INVESTMENT ON THE LENGTH OF TIME PILOTS FLY INTO DEGRADED WEATHER

by

BONNIE M. SAXTON
B.S., University of Central Florida, 2006

A Thesis Submitted to the
Department of Human Factors & Systems
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Human Factors and Systems

Embry Riddle Aeronautical University
Daytona Beach, FL
Spring, 2008

THE INFLUENCE OF MOTIVATION AND INVESTMENT ON THE LENGTH OF TIME PILOTS FLY INTO DEGRADED WEATHER

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

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Abstract

Approximately 75% of weather-related accidents result in fatalities and are a primary safety concern in aviation. This study attempted to understand how financial motivation and time investment influence the length of time pilots fly into degraded weather. The sunk-cost effect claims that financially motivated pilots would continue longer when weather is encountered late in the flight. The results revealed that the financially motivated pilots continued longer than the non-financially motivated pilots when weather was encountered early in the flight. These results support the situation assessment hypothesis and cognitive anchoring. Specifically, how pilots assess the situation and utilize information obtained before making a decision can influence their decisions. Further research is needed to understand this relationship to possibly reduce the number of weather-related accidents and associated fatalities.

Acknowledgements

I wanted to acknowledge the people who have helped me throughout this entire process, because without them, none of this would have been possible. I wanted to thank my parents, Henry and Betty Klepacki, for the many sacrifices they have made to give me the awesome life I have today. Because of their sacrifices, I have been given the opportunities to accomplish multiple achievements, and without their encouragement and love, the life I live would be different. I appreciate what they have done for me and how they continue to bless my life each and every day.

I wanted to thank Trudy and Randall Ward for their help and immense influence they have had in my life while working to obtain my masters. They opened their home, offered cooked meals, provided a "warm" bed, and were good company, whenever I needed it. Their home assisted me with the ability to sleep 15 minutes away from Embry-Riddle saving me hours of driving and allotted more time for homework or badly needed sleep. They may never know how truly thankful I am for their hospitality and kindness in making their home not just a place to stay but a replica of my own home.

I also wanted to thank Frank Hannigan for all the help he has offered me over the past two years at Embry-Riddle. Never having been exposed to aviation prior to Embry-Riddle, he has served as a subject matter expert, answering all my aviation related questions. I am very grateful for his willingness to help me with anything, anytime, or anywhere. I am especially grateful for his help and aviation expertise while acting as air traffic control during data collection. Frank is one of the primary contributing factors behind why I was able to graduate on time because without his help in conducting my experiment, I would not have completed my thesis in two years. Because of Frank's help

while collecting data, his attention to detail, his hard work ethic, his professional attitude, and friendship, the inspiration to work harder and aspire to be a better student resulted. I am forever indebted to him and hope to one day help him as much as he has helped me, holla!!!

Next I would like to acknowledge the person who has influenced me the most over the past two years. Dr. Albert Boquet never doubted my ability to accomplish tasks even in my first few months as a student and colleague in the unfamiliar aviation environment at Embry-Riddle. He has been my mentor who has given me advice about everything from school related issues, career opportunities, and countless thesis related concerns, as well as many other topics. He was always available to help no matter how busy or stressed he seemed, and always managed to make light of bad situations, usually by making crazy comments. I am very thankful to have worked and learned what I have from Dr. Boquet these past two years, and will always look at my time at Embry-Riddle with happy memories. Above all, the most important thing to remember is to deliver the liver to the ever loving liver lovers!!!

Last, I would like to acknowledge my husband, Mike Saxton, as the one who has supported me throughout our entire relationship, and as the person I love more than anyone in the world. He was the one who encouraged me to keep working when the workload seemed impossible, and celebrated with me when I successfully accomplished what I thought was impossible. Mike was one of the primary reasons I was able to graduate on-time because he understood and supported my decisions to work late into the night, over the weekend, during fun events with friends (e.g., birthday parties, etc), as well as the nights spent at his mom's leaving him home alone. His love, understanding, and sacrifices did not go unnoticed, and I hope I can encourage him as much as he encouraged me as he develops into a very talented engineer. He is my best friend, my soul mate, and my partner that I want to venture through life with forever and a day.

I am thankful for the many blessings in my life and owe all of my accomplishments to God, family, friends, fellow students and facility members that helped me every step of the way.

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Introduction

Overview of General Aviation (GA) Flight and Weather Information

Accident Example

On January 31, 2004, a pilot and two passengers boarded a Cessna 414A in Honolulu, Hawaii and were scheduled to arrive at Hilo, Hawaii to pick up a patient. Even though weather reports indicated visual and instrument meteorological conditions, the pilot filed a visual flight rules (VFR) flight plan. Shortly after takeoff, the aircraft crashed into trees and mountainous terrain located 21 miles from the destination, nearby Laupahoehoe. The accident investigation found that the pilot was current on all certifications and the aircraft logbook showed no reason for mechanical failure.

Although the National Weather Service issued a weather advisory to all en route pilots to notify them of the hazardous flying conditions; the pilot elected to fly a VFR flight plan and ultimately flew into instrument meteorological conditions. The pilot's decisions resulted in the deaths of the pilot and the two passengers on board the flight, and became another data point in the legacy of weather-related aviation fatalities (National Transportation Safety Board, LAX04FA113).

It is the pilot's responsibility to evaluate their experience and skill level as well as the performance parameters of the aircraft to handle the conditions while flying. Researchers have tried to answer the question of why some pilots purposefully or accidentally fly in degraded weather conditions, yet the data remains equivocal. The current investigation attempted to outline current theories associated with weather-related aviation accidents, and test possible theories as to why some pilots fly into degraded weather.

GA Background: Accident and Fatalities

Many general aviation (GA) accidents occur every year and since weather related accidents are one of the leading causes of death among GA pilots, this leads to a primary concern for GA safety (Batt & O'Hare, 2005; Knecht, Harris & Shappell, 2005; O'Hare & Wiegmann, 2001). The National Transportation Safety Board (NTSB) states that of the 39,199 GA accidents that occurred between 1987 and 2006, a total of 7,611 were associated with fatalities. As shown in Figure 1, the accidents per year have decreased overall but the total number of fatal accidents have remained relatively constant (National Transportation Safety Board [NTSB]).

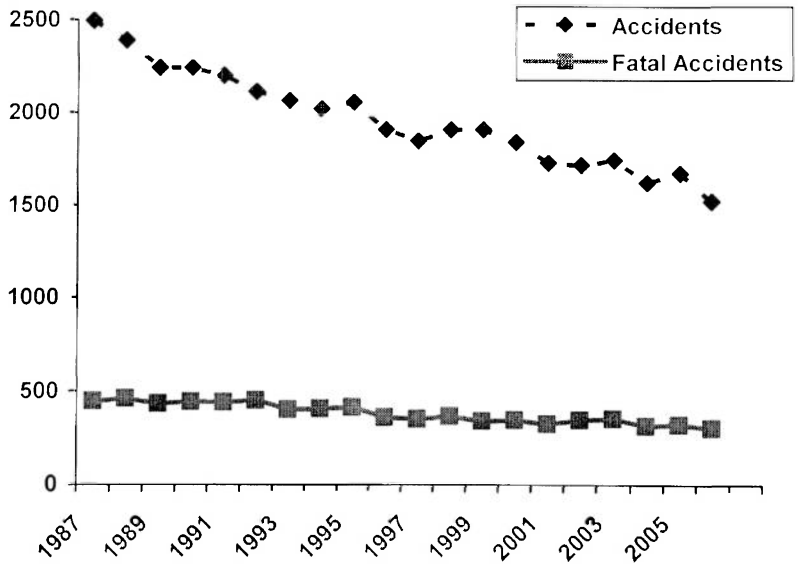

Figure 1. All General Aviation Accidents that Occurred Between 1987 and 2006. (From Table 10 at http://www.ntsb.gov/Aviation/Stats.htm)

In Figure 2, the accident and fatality rate was computed per 100,000 flight hours for the accidents between 1987 and 2006. A downward trend can be observed for the accident rate while the fatality rate has remained relatively constant. These findings are consistent with the findings in Figure 1 that show over the past two decades the number of accidents has decreased while the number of fatal accidents have remained unchanged (NTSB).

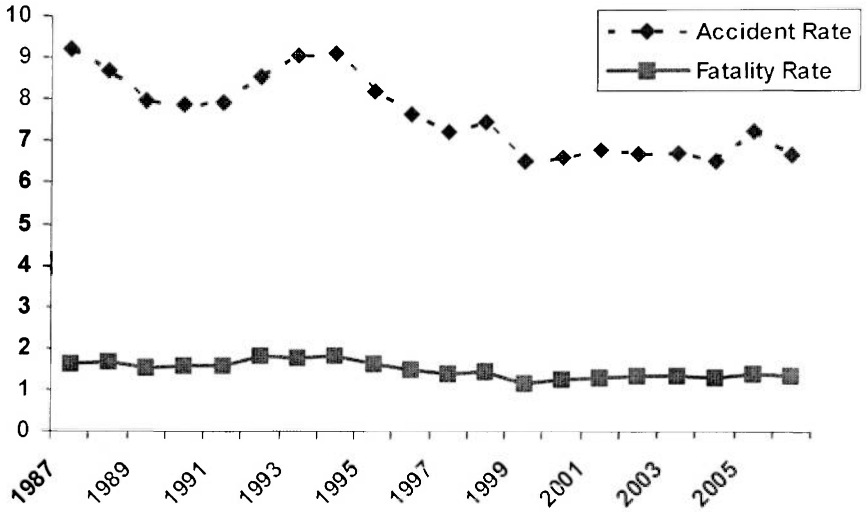

Figure 2. The Accident and Fatality Rates Per 100,000 Hours Between 1987 and 2006. (From Table 10 at http://www.ntsb.gov/Aviation/Stats.htm)

A GA accident can occur because of many of factors including mechanical failures, pilot error, lighting (e.g., daytime, nighttime), terrain (e.g., mountain, water) and weather, just to name a few (Detwiler, Hackworth, Holcomb, Boquet, Pfleiderer, Wiegmann, & Shappell, 2005). Too complicate matters further, these factors rarely occur in isolation, but rather in combination with one another.

Weather Related Accidents

While technological advances in the cockpit have made additional information available to GA pilots, weather-related accidents continue to plague the GA population

(Wiggins & O'Hare, 2003). Every year, 5 to 9 percent of all GA accidents are weather-related (National Transportation Safety Board [NTSB], 2005). General aviation has statistically shown that 3 out of 4 weather-related accidents are associated with fatalities (O'Hare & Wiegmann, 2001). These statistics are evident in the United States as well as other countries. Batt and O'Hare (2005) found that weather-related accidents are also a problem for pilots in Australia. Of the weather-related accidents analyzed from the Australian Transport Safety Bureau, 75.6% of the accidents were associated with fatalities. The high number of weather-related accidents shown by the statistics for the U.S. and Australia further illustrates the need to understand the underlying factors associated with weather related accidents. However, it is necessary to first understand what the Federal Aviation Administration (FAA) considers a weather related accident.

Visual Flight Rules (VFR) Flight into Instrument Meteorological Conditions (IMC)

Many terms within GA are used to explain different devices, rules, and conditions while flying. The terms visual meteorological conditions (VMC) and instrument meteorological conditions (IMC) are used to define the weather conditions that a pilot encounters while flying. The terms visual flight rules (VFR) and instrument flight rules (IFR) are the rules that govern flying through different weather conditions (*Private pilot manual*, 1997). The terms VFR and IFR are used to describe the pilot's flight path while VMC and IMC describe the conditions in which the pilot is flying in. It is perfectly acceptable for a pilot to fly an IFR flight plan into VMC weather conditions but it is a violation of FAA regulations for a pilot to fly with a VFR flight plan into IMC (*Private pilot manual*, 1997).

A pilot can fly through VMC or IMC conditions by using VFR or IFR to navigate through these conditions. VFR or IFR consists of specific Federal Aviation Regulations (FARs) for cloud clearance and visibility requirements. If weather conditions are below specified VFR minimums, the pilot is required to file an IFR flight plan instead of VFR flight plan (*Private pilot manual*, 1997). In order to fly in IFR conditions the pilot must have the proper instrument certifications and a plane equipped with FAA approved IFR instrumentation. The ideal flying situation for a pilot is VFR with visibility up to three miles of visibility and a sky clear of clouds (Nall Report, 1998). A brief discussion of the established FARs weather minimums will follow as well as how pilots properly access weather information to make the proper decisions between a VFR and IFR flight plan.

Weather Minimums

There are two kinds of flying airspace, controlled and uncontrolled, which can be further divided into six flight classes. GA primarily flies in uncontrolled airspace or class G (AOPA, Air Safety Foundation). Each flight class has different weather minimums for day and night flights which must be followed for a flight to be considered VFR. For instances, a basic VFR weather minimums for a class G daytime flight is between 1,200 feet and 10,000 feet including one mile of visibility with 500 feet below cloud clearance, 1,000 feet above cloud clearance, and 2,000 feet horizontal cloud clearance (Federal Aviation Regulation FAR 91.155). For a pilot to be classified as flying in IMC, the weather conditions are classified as more degraded or lower than the stated VFR minimums.

Source of Weather Data. Because flying occurs in a dynamic environment the pilot is required to monitor the environment for continuous changes. In aspects of weather, pilot must pay attention for the indication that weather is degrading to make the proper decisions to ensure safety of the flight. The pilot has the ability to access weather information through a number of resources.

Before takeoff, the pilot must obtain a flight plan and a weather report. A computer generated weather report can be obtained through Direct User Access Terminal Service (DUATS), or over the phone through Flight Service Station (FSS). DUATS and FSS allows the pilot access to weather information before planning a flight, filing and closing the flight plan, and while making changes to the flight plan (Federal Aviation Administration [FAA], 1999) While taxing on the runway the pilots can affirm the weather report through Automatic Terminal Information Service (ATIS). ATIS is a report constantly verbalized over a particular frequency at an airport to provide pilots with information that is crucial to the safety of the flight. Some of the information provided by ATIS is information on active runways, airport call signs used by the pilots uses to communicate with the controllers, weather information on wind speed and direction, visibility, ceiling, temperature, dew point, and altimeter settings. Each report is given a distinct name (e.g., Alpha, Tango, etc.), which indicates to the pilots when a new report has been generated containing new information. The report is generated about every 45 minutes and is repeated until a new report is generated (O'Brien, FAA website).

Even with specified weather minimums and a weather reporting system, pilots often find themselves flying into degrading weather comprising the safety of the flight. Some reasons why pilots fly into degraded weather exists in the literature and will be discussed further.

Factors Associated With Flying Into Degraded Weather

While researchers have tried to explain why pilots fly into weather, the data has remained equivocal. However, a number of factors have been identified that may contribute to why pilots fly into degraded weather. A characteristic necessary for safe flying is a pilots' ability to make the right decision at the appropriate moment. The flight can become very dangerous if the pilot encounters degrading weather and the pilot must quickly make the right decision. In some circumstances the consequences that can result if a pilot makes the wrong decision or makes the right decision to late is death. The decision making process is important throughout the entire flight and a description of the decision making process will be discussed as well as aeronautical decision making.

Cognitive Approach to Decision Making

Decisions are made every day dealing with ordinary to very important matters. For example, a person makes the decision to wear black pants over grey pants whereas that same person can later make the decision to continue flying into degraded weather or divert. According to Slade (1994), decision making is a process that encompasses a series of smaller decisions that occur within a process that can be broken down into eight discrete actions (see Figure 3). These eight actions include: (1) identifying the problem, (2) identifying the alternatives, (3) choosing a usual action, (4) evaluating alternatives, (5) choosing among alternatives, (6) effecting the choice, (7) generating new alternatives, and (8) abandoning problem (Slade, 1994).

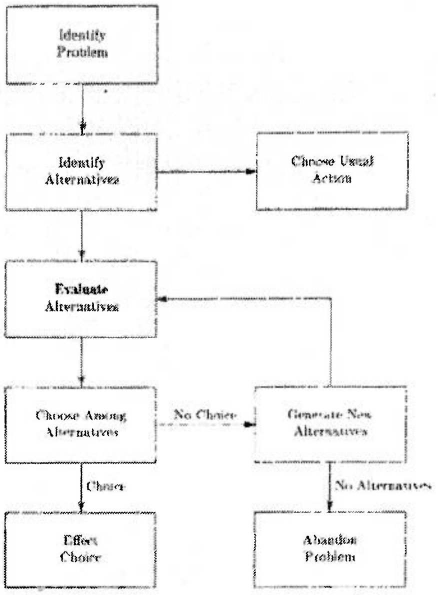

Figure 3: Slade's (1994) Process of Decision Making
(From Slade, 1994)

Before action can be taken a person must realize that a problem exists. Once a problem is identified, appropriate alternatives (i.e., solutions) can be determined. According to Slade's (1994) decision making model usual actions can be identified as alternatives or effective choices that a person has used in the past that has proven effective in solving a problem. The established alternatives are evaluated based on the consequences and advantages as well as against the previous experiences the person had with the alternative. After evaluation, the alternatives are ranked and the highest ranked alternative is chosen. If any of the alternatives are ranked equally the alternatives are further analyzed for the best solution. Once the best alternative is identified, a solution is then chosen and put into action. In some cases all the alternatives are inadequate for solving the problem and a list of new alternatives is created. In the end, if no satisfactory solution is found, the problem is abandoned.

Slade's (1994) description of the decision making process is a basic overview of the components involved when making a decision. Similar to Slade's decision making approach, Jensen's (1995) Judgment model has been used to explain decisions made within aviation or in the cockpit.

Aeronautical Decision-Making

Jensen's (1995) Judgment Model can be used to explain a pilot's judgment process when faced with making a decision in aviation. Jensen's (1995) Judgment Model is comprised of eight stages, which includes: (1) problem vigil, (2) recognition, (3) diagnosis, (4) alternative identification, (5) risk, (6) background factor, (7) decision, and (8) action stages (see Figure 4).

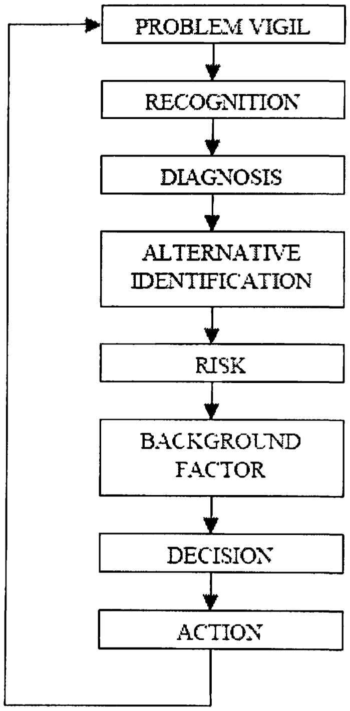

Figure 4: Jensen's (1995) Judgment Model
(From Wiegmann & Goh, 2000)

It is emphasized in the problem vigil stage that the pilot must be alert and aware of changes in the environment. The pilot obtains information from the environment through the human senses. For example, a person's vestibular, kinesthetic, tactile, and olfactory system aid in the identification of changes but the primary senses used in understanding the environment are the eyes and ears for sight and hearing. When a pilot becomes distracted they risk missing changes in the environment, allowing a situation to become dangerous (Jensen, 1995; Wiegmann & Goh, 2000).

In the problem recognition stage, a pilot must recognize the current situation as a threat to the safety of the flight and the passengers on board. Whether or not a pilot is successful in identifying the risks is dependent on their perception of the situation and what they expect may happen. Often times our perceptual system delivers information through the senses to the brain to be interpreted but is processed incorrectly. The reason why information is processed incorrectly is because information delivered to the brain is in simplest form. The purpose of the simplified information is to allow for easier information processing, which speeds up the recognition of a problem. Because our perceptual system does not give a complete account of the situation due to misinterpretations of the information occur when our brain fills in the missing information. For example, in the corridor illusion the cylinders appear to be different sizes because our perceptual system places the cylinders in line with the context (see Figure 5). Our senses take the simplest message and our brain interprets the cylinders as different because perceiving the cylinders as the same requires more information processing and energy. Just like a perceptual error is made in the perception of the size of the cylinders, pilots make perceptual errors in aviation. A pilot may not perceive weather as dangerous and make a judgment error when deciding to fly VFR into degraded weather conditions (Jensen, 1995).

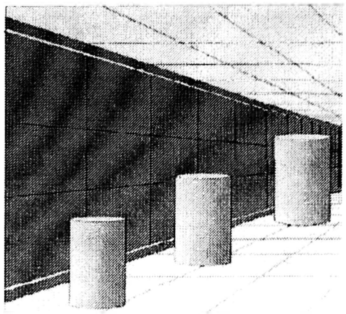

Figure 5: The Corridor Illusion
(From Jensen, 1995)

In addition to perception, a pilot uses past experiences or expectancy to judge the likelihood of certain outcomes. Expectancy can be defined as the "thought patterns which tend to bias our interpretations of our environment" (Jensen, 1995, p. 41). A pilot reduces the level of information that needs processing by using past experiences to predict what will occur in current or future situations. As explained earlier, the perceptual system can lead to judgment errors, and aviation training that focuses on using knowledge, experience, and maintaining an alert state can counteract these types of perceptual judgment errors (Jensen, 1995).

In the diagnosis stage, the pilot must gain an understanding of the nature of the problem before solutions can be created to fix the problem. When a problem is identified, the pilot must understand the current situation and how any change to the environment can influence the current state and the circumstances in the future. If a pilot makes an incorrect diagnosis the situation could become unsafe or even fatal, and unfortunately, pilots are required to diagnosis a situation very quickly (Jensen, 1995). To make quick decisions, a pilot can use understanding of past experiences with similar situations and knowledge of hazards to make correct diagnoses (Wiegmann & Goh, 2000).

In the alternative identification stage, the pilot identifies multiple courses of action that can be used to resolve the problem. The pilot must choose an alternative that will keep the aircraft and passengers safe by using a combination of creativity, knowledge of the aircraft, knowledge of the environment, and knowledge of the aviation system as a whole. In the risk stage, the pilot is required to associate the risks with each alternative based on a number of factors like the skill level of the pilot, reliability of the weather forecast, and the reliability of the aircraft. The background factor stage affects the judgment process by representing the influencing motivational factors that prevent a person from making purely rational decisions. Factors like duty, economics, adventure, commitment, ego, social pressures from peers, superiors, passengers, co-workers, and physiological pressures from illness and fatigue influence every cognitive decision the pilot makes (Jensen, 1995).

In the decision stage, the pilot chooses a specific course of action and prepares to implement the decision. At this time, the pilot is about to make a decision that could result in negative consequences. In the final stage, the action stage, the pilot takes all the information about the situation, concerning the problem and appropriate solution, and puts the solution into "action" (i.e., physically and mentally) to solve the problem. As shown in Figure 4, a feedback loop is present in Jensen's (1995) Judgment Model. Since the aviation environment is dynamic, the feedback loop in Jensen's (1995) Judgment Model represents the iterative nature of decision making. Each stage is completed for one problem at a time, and after the solution has been implemented, the entire process is repeated whenever a new problem arises. A pilot does not make a decision based on the serial order of accomplishing these stages. Each stage is not independent of each other and can influence one another while making a decision. Jensen's (1995) judgment model is shown as a linear model for instructional purposes to understand the decision making process.

Aeronautical Decision-Making While Flying Through Degraded Weather. A pilot must make a series of decisions when flying through weather, and the dynamic nature of flying requires pilots always pay attention. Many times pilots receive cues that weather is changing but continue to fly VFR into degraded weather (Burian, Orasanu, & Hitt, 2000). When pilots receive cues that weather is deteriorating and continue into degraded weather, it is said that a plan continuation event (PCE) has occurred. Burian, Orasanu, and Hitt (2000) investigated whether pilot's experience level (e.g., flight hours) and degradation of weather affected the number of PCEs committed. The results revealed that experience level played a role in the occurrences of PCEs. The pilots in the lower 25th percentile for flight experience hours were more likely to commit a PCE than the pilots in the upper 75th percentile for flight experience. It was also found that more PCEs are committed when flying into gradually degrading weather than weather that degrades quickly. The changes in gradually degrading weather are harder to perceive and can lead some pilots to misperceive weather conditions. Both experience level and perception of weather conditions may play a role in whether pilots fly into weather. Some factors according to Wiegmann and Goh (2000) will be discussed to explain why some pilots fly into degraded weather.

Wiegmann and Goh (2000) added four factors alongside Jensen's Judgment Model to help explain why some pilots fly into degraded weather. These factors include (1) situation assessment, (2) risk perception, (3) motivation, and (4) decision framing (Figure 6). The concepts of situation assessment, risk perception, motivation, and decision framing have been associated with the decision making steps of Jensen's (1995) Judgment Model to conceptualize how these four factors play a role in pilot's decision making abilities when flying into degraded weather.

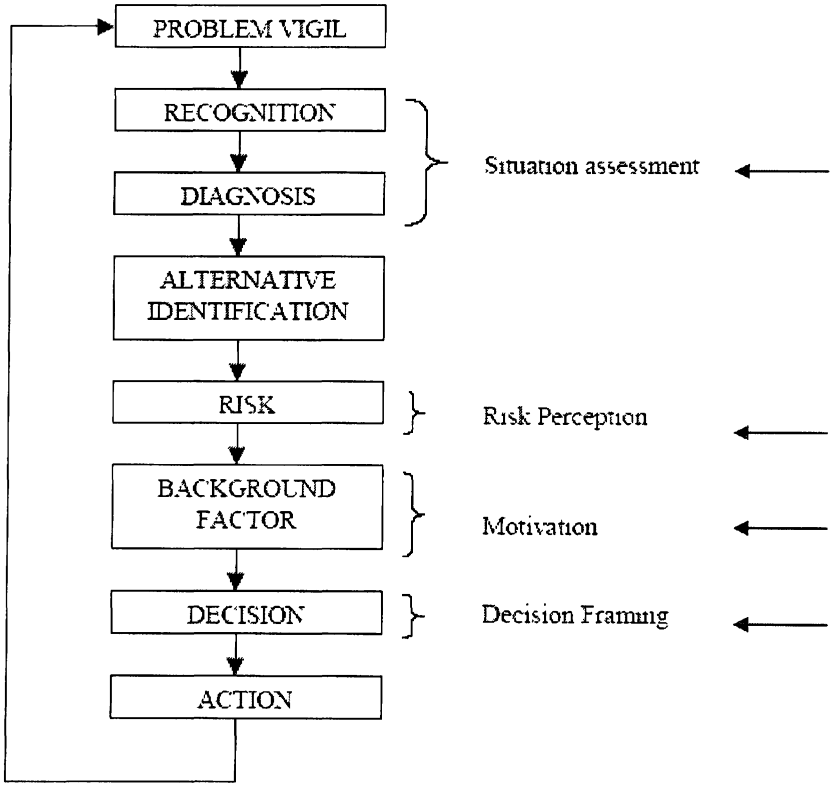

Figure 6: Four Factors From Jensen's (1995) Judgment Model (From Wiegmann & Goh, 2000)

When considering situation assessment skills, Wiegmann and Goh (2000) state that according to the situation assessment hypothesis, some pilots fly VFR into IMC because they incorrectly assessed the hazards associated with the situation (Goh & Wiegmann, 2002a; Goh & Wiegmann, 2001b; Wiegmann, Goh, & O'Hare, 2002). Reasons why a pilot assesses a situation incorrectly can include inexperience and poor hazard awareness. Inexperienced pilots lack the ability that experienced pilots have to quickly and efficiently identify weather hazards. A pilot who has more experience with degrading weather will identify weather changes faster than a pilot who has little or no experience. It is harder for a pilot to discriminate gradual weather changes, from minimum VFR conditions to marginal VFR and finally to IFR than in a situation where drastic weather changes occur. When weather degrades gradually, the pilot does not notices the changes and may fly into degrading weather without realizing that he or she has done so until it is too late. A pilot may also have poor hazard awareness and simply underestimate the hazards associated with situation. For example, a pilot with poor hazard awareness will consider weather as an unlikely cause of an accident and, as a result, fly into weather (Wiegmann & Goh, 2000).

In addition to situation assessment, Wiegmann and Goh (2000) claim that risk perception or poor risk perception can contribute to why some pilots fly into weather. Risk can be defined "as the likelihood of suffering a loss due to a hazard" (Wiegmann and Goh, 2000, p. 3). A pilot may assess degrading weather accurately but underestimate the risk (e.g., crashing and/or death) associated with the situation. One reason why pilots underestimated risks is because a pilot may be overconfident in their abilities to control the aircraft. Pilots are trained to be confident in their skills and abilities and a by-product of this training, pilots may become overconfident and suffer what is known as confidence calibration.

Knecht, Harris, & Shappell (2005) describe confidence calibration as the degree to which a pilot's confidence level in accomplishing a task truly matches their ability to accomplish a task. The zero risk theory can be applied to aviation to explain the relationship between a pilot's confidence level and risk perception in a situation. The zero risk theory states that, "the perceived risk in a situation is the product of the perceived likelihood of a hazardous event and the importance attached by the individual to the consequence of the event" (Hunter, 2002, p. 1). What this means is that as a pilot's confidence level increases the perceived level of risk for a situation diminishes. A pilot gains experience through training in a situation the perceived level of risk for that situation diminishes (Hunter, 2002).

Wiegmann and Goh (2000) claim that motivational factors (e.g., personal, social, or financial factors) can lead some pilots to fly into degraded weather. For example, a pilot experiences personal pressure to continue into degraded weather when the pilot wants to reach the destination (i.e., "get-home-itis") to spend time with a love one or family member. Social pressures to continue flying into degraded weather can come from the pilots' organization (e.g., time pressure, etc.) or from the passengers in the aircraft. In respect to financial incentive, pilots are only paid when "in-flight" and the decision to stay grounded or divert to an alternative airport is unappealing to the pilots and to the passengers. These pressures bias the pilot's decisions regardless of whether the assessment of the situation suggests otherwise.

Last, Wiegmann and Goh (2000) claim that based on how the pilots view the framing of the alternatives (e.g., positive or negative) can lead some pilots to fly into degraded weather. Whether a pilot makes a decision between a risky or safe choice is dependent on the decision framing of the alternatives. For example, when a pilot is faced with degrading weather and must make the decision to divert or continue whether the pilot views this decision as a loss or gain will affect his or her decision to divert or continue. If a pilot views the decision to divert as a loss of investment (e.g., time, money or effort), the pilot will take a risk-seeking outlook and make a risky decision to fly into degraded weather. On the other hand, if a pilot views diverting the flight as a gain (e.g., increasing flight safety), a risk-averse outlook will be taken and the pilot will make the decision to divert to a safe alternative (O'Hare & Smitheram, 1995; Wiegmann & Goh, 2000; Wiegmann, Goh, & O'Hare, 2001). As shown by the Prospect Theory Value Function (see Figure 7), the gain curve is much steeper than the loss curve because people have extreme responses to a choice involving a loss. If a pilot is confronted with a decision that could result in a negative outcome (e.g., loss of resources, diverting) the pilot may chose another decision to maintain that investment (i.e., continuing into degraded weather).

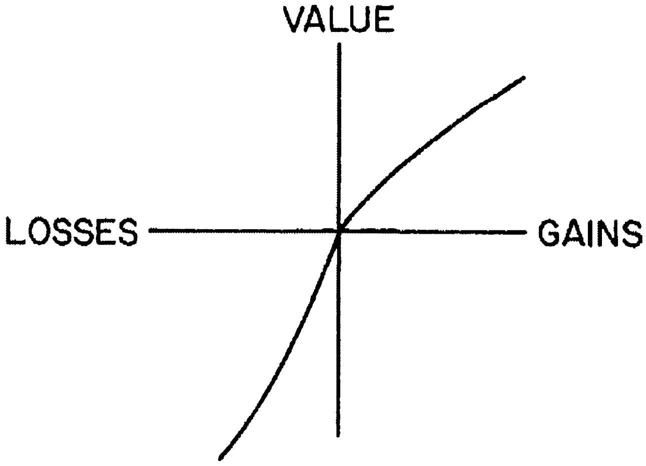

Figure 7: The Prospect Theory Hypothetical Value Function
(From Kahneman & Tversky, 1984)

A pilot views a decision as a loss or gain in reference to their current position rather than the final outcome (Kahneman & Tversky, 1984). Because of this, a pilot will view the decision frame as a gain or a loss based on the proximity of accomplishing the goals of the flight. One of the pilot's goals is to arrive at the destination, and the closer the pilot is to accomplishing that goal, the higher the chance the pilot will continue into degrading weather. The pilot's decision to continue into degraded weather to arrive at the destination can be influenced by the sunk cost effect or what is known as "get-home-it-is" (Goh & Wiegmann, 2002a; Goh & Wiegmann, 2001a; Wiegmann, Goh, & O'Hare, 2002). The sunk cost effect is an irrational economic behavior that causes a person to continue participating in a task, even if continuing that task puts that person at risk (Arkes & Blumer, 1985). Once a pilot has invested resources in the flight (e.g., time and money) the decision to continue into degraded weather will be more likely, sometimes regardless of life-threatening factors.

Jensen's (1995) Judgment model is one model that describes the steps involved while making a decision. When trying to understand the process involved in aeronautical decision making, situation assessment, risk perception, motivation, and decision framing must be considered and understood. These four factors were incorporated into Jensen's (1995) Judgment Model and are located alongside the appropriate steps (see Figure 7). Situation assessment is paired with the recognition and diagnosis stages and aids with a pilot's ability to recognize the problem and identify a diagnosis for that problem. Risk perception is paired with the risk stage because a pilot must identify the risks associated with a problem before the risks can be understood. The background factor influences a person's ability to make irrational decisions and many times motivation is a key component that influences our decision-making. Depending on the type of motivation (e.g., personal or social pressures), these pressures influence whether we will make a good or bad decision. Finally, decision framing is paired with the decision step because the way in which the pilot views the alternatives, influences what decision will be made. In other words, the way in which the decision is framed (e.g., gain or loss) determines what the pilot will choose. Once a decision is chosen and put into action, the outcome from this decision may be very different than an outcome from another decision. This is why it is important especially in aviation that the right decision is made at the appropriate time. These four factors have an integral role in aiding or inhibiting a pilot's ability to make safe weather-related decisions and must be considered when analyzing the reasons why pilots fly into degraded weather.

Focus of the Study

Rationale

Both motivation and the sunk-cost effect were investigated in this study and three hypotheses existed for the results. Because money is a strong motivating factor, half of the pilots were financially motivated by a bonus payment for reaching the destination. The remaining group of pilots did not receive a bonus payment and were not financially motivated to reach the destination. The pilots that received the financial motivator were labeled as being extrinsically motivated (EM) while the pilots that did not receive the bonus payment were labeled as being intrinsically motivated (IM). The purpose behind this design was to create a scenario that would encourage the EM pilots to continue longer into degraded, while the IM pilots would be more inclined to divert when they encountered degrading weather.

According to the prospect theory, if a decision is framed as a loss (e.g., time, money, effort, etc.) the probability of a pilot continuing the flight into degraded weather increases. According to the sunk cost effect, pilots will continue into degraded weather after an investment (i.e., money, time) has been made. The pilots that encounter weather closer to the destination or late in the flight will continue into weather longer than pilots who encounter weather farther away from the destination or early in the flight. The pilots who encounter degraded weather late in the flight have invested more in the flight and will have a stronger desire to reach the destination than the pilots who encounter weather early in the flight who have invested less (Goh & Wiegmann, 2002a).

Statement of Hypotheses

Hypothesis One. It was hypothesized that a significant main effect for motivation would be found. It was expected that the EM pilots would fly longer into degraded weather than the IM pilots.

Hypothesis Two. It was also expected that a significant main effect for investment would be found. The pilots who encounter degraded weather late in the flight (WL) would fly longer into degraded weather than the pilots who encounter degraded weather early in the flight (WE).

Hypothesis Three. Last, it was hypothesized that the significant main effects would be modified by an interaction between investment and motivation. A significant difference would be found between the EM pilots and the IM pilots who encountered weather early in the flight. Overall, it was expected that the EM pilots who encountered weather late in the flight would continue the longest into degraded weather while the IM pilots who encountered weather early in the flight would continue into degraded weather the least amount of time.

In this study, a group of pilots encountered degraded weather early in the flight while the remaining group of pilots encountered weather late in the flight. According to the sunk cost effect, the pilots who encountered weather late in the flight would continue longer into degrading weather than the pilots who encountered degrading weather early in the flight. The pilots who encounter degrading weather late in the flight have invested more resources (e.g., time, money, and resources) in the flight and are closer to the final destination these pilots will continue longer into weather than the pilots who encounter degraded weather early in the flight or invested less in the flight.

Statement of Problem and Research Question

The reason for conducting this research was to better understand why pilots fly into degraded weather. Narrowing our focus, the research question that existed for this study was whether pilots would continue to fly into degraded weather longer after investment and motivational factors have been implemented.

Method

Participants

The sample population consisted of 40 instrument rated pilots from Embry-Riddle Aeronautical University. Rather than using VFR pilots, instrument rated pilots were used as the sample in the study because it was assumed that instrument rated pilots had the experience level to recognize degraded weather.

Participant Demographic Information. After signing the informed consent form (Appendix A), the pilots completed the demographics data flight performance questionnaire (Appendix B) on background flight information. The following demographic information was gathered: (1) age, (2) number of hours flown in VFR, (3) number of hours flown in IFR, and (4) number of hours flown in technically advanced aircraft (TAA) (see Table 1). The pilot's VFR, IFR, and TAA hours were focused on rather than certifications since the pilot's flight hours is more indicative of their experience level than just certification level. For example, a pilot with a commercial aircraft certification was viewed as having a higher certification when compared to a pilot with a private pilot's license. Having the commercial certification does not necessarily equate to more experience than having a private pilot's license. The private pilot may have more flight hours than the commercial pilot but is viewed as less experienced when certification is considered alone when determining experience level. The data shows some variability because of a few outliers that existed in the flight hours reported by the pilots.

Table 1. Table of Means for Age, VFR, IFR, TAA Hours (standard deviations)

Conditions	Age	VFR Hrs	IFR Hrs	TAA Hrs
Early Weather (12 mins) Externally Motivated	22.1 (3.14)	243.5 (145.2)	34.8 (29.57)	57.9 (44.09)
Early Weather (12 mins) Internally Motivated	20.2 (1.23)	207 (90.31)	43 (59.26)	38 (22.01)
Late Weather (30 mins) Externally Motivated	21.2 (0.78)	303 (339.39)	51.9 (29.82)	29.8 (24.39)
Late Weather (30 mins) Internally Motivated	21.9 (1.85)	387.5 (439.06)	37.8 (30.75)	85.9 (58.38)
Total	21.35 (2.03)	285.25 (287.39)	41.86 (38.46)	52.9 (44.31)

Design

The experimental design was a 2 (investment, weather early and weather late) x 2 (motivation, EM and IM) between subjects design, with the dependent measure being the length of time the pilots continued into degraded weather. The pilots were randomly assigned to one of the four conditions that varied in terms of investment and motivation.

Investment. Half of the pilots encountered degrading weather after completing about 25 percent of the flight, or weather early in the flight, while the remaining half of the pilots received degraded weather after completing about 75 percent of the flight, or weather late in the flight. Since it was estimated that the flight would last for 42 minutes the pilots who encountered weather early in the flight experienced degrading weather 12 minutes into the 42 minute session, while the pilots who encountered degraded weather late in flight experienced degrading weather 30 minutes into the 42 minute session. A description of the scenario used for the pilots who encountered degraded weather late is located in Appendix D, while the scenario for the pilots who encountered degraded weather is located in Appendix E.

Motivation. The flight was designed as a life flight. The pilots were told they would be delivering a liver from Daytona Beach to Gainesville. The purpose of making the life flight was to motivate all the pilots to arrive at the destination. All of the pilots were paid 25 dollars for participating in the study. To see if an additional financial payment would motivate the pilots to fly longer into weather, half of the pilots were randomly assigned to an extrinsic motivation, EM, condition, which these pilots received an additional 20 dollars if they arrived at Gainesville. If the pilot decided to divert to an alternative airport during the flight and did not arrive at the Gainesville, they received 25 dollars for participating but did not receive the additional 20 dollar bonus payment. As a way to manipulate financial motivation, the remaining group of pilots did not receive a bonus payment for reaching Gainesville and were labeled as the intrinsic motivated, IM, condition. Regardless of whether the IM pilots landed in Gainesville or diverted, the pilots received 25 dollars for participating in the study.

Time into Degraded Weather. The length of time each pilot flew into weather was measured until their diversion time or their landing time at Gainesville. For example, if a WE pilot decided to divert at the point where weather began to degrade, the length of time the pilot flew into weather until the pilot diverted was documented. Once it was indicated that the pilots diverted from the flight plan to an alternative path, the pilots were allowed to continue flying to an alternative airport to land. If the pilot decided to continue to Gainesville, the length of time the pilots flew into degraded weather from the point at which weather began to degrade to landing at Gainesville was documented.

Before the analyses were conducted the length of time the pilots flew into degraded was restricted to 15 minutes. If the pilots continued after 15 minutes, their time into weather was indicated at 15 minutes and marked as continuing to the destination. The reason the 15 minute cutoff time was used in all the flight conditions was to hold the length of time the pilots could continue into weather consistent between the pilots who encountered weather early in the flight (WE) pilots and those pilots who encountered weather late in the flight (WL) pilots. This way the WE pilots did not have more time to fly into degraded weather than the WL pilots who had about 15 minutes of flying time after degraded weather was encountered.

Apparatus and Materials

Simulator. The experiment was conducted in the Technologically Advanced Aircraft Performance (TAAP) Laboratory, using an Elite flight simulator (Figure 8). The ELITE flight simulator is a technically advanced aircraft equipped with a GARMIN interface. The GARMIN interface has a multiple functional display (MFD), traffic information service (TIS), and moving map, which was programmed by the investigator. The pilots were not allowed to manipulate any information on the moving display and no traffic information was presented. Microsoft Flight Simulator 2004 was the software used to operate the Elite flight simulator as the pilots flew the Cessna 172. The flight scenario was projected using a liquid crystal display (LCD) projector onto an eight foot screen located in front of the simulator. A stop watch was used to track the length of time the flight scenario lasted and the length of time the pilots flew into degraded weather.

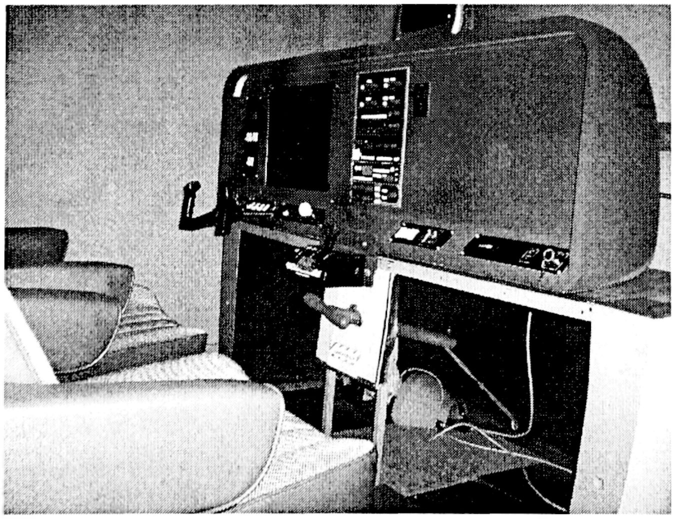

Figure 8: Photograph of the Elite system Cessna 172 simulation device.

Pre-Experimental Questionnaire. The pilots completed two questionnaires before starting the flight scenario. These questionnaires included the informed consent and the demographic questionnaire.

Post-Experimental Questionnaire. After the flight scenario, the pilots completed the post-experimental questionnaire, the Federal Aeronautical Decision Making / Judgment Questionnaire (FADM/JQ). The FADM/JQ was modified by Blickensderfer and Summers from the Federal Aviation Administration Pilot Survey created by Driskill, Weissmuller, Quebec, Hand, and Hunter (1998). The questionnaire revised by Blickersderfer and Summers was reviewed for weather related scenarios and used to comprised the FADM/JQ (see Appendix C). This questionnaire assessed the pilots' decision making process through scripted weather related scenarios. The pilots were asked to read the questions and rank the likelihood they would perform each action on a 5 point Likert Scale, which ranged from 1 meaning a highly unlikely option or unlikely course of action and 5 indicating a highly likely option or likely course of action.

Degradation of Weather for Every Condition

The entire flight scenario was created by a subject matter expert, which included the weather manipulations. All the flight scenarios started with the same VFR weather condition indicated as the initial weather setting presented in Table 2. These conditions were specified in the weather manipulation settings of Microsoft Flight Simulator. In an effort to make weather seem as though it was degraded gradually, the first change occurred early (12 minutes) or late (30 minutes) into the flight and the next two changes occurred after one minute intervals had passed. The changes from initial weather settings to the first degradation included a change from 10 miles of visibility to 5 miles of visibility and a change from a cloud base of 8,000 scattered to 5,000 broken (i.e., from 4/8 scattered to 5/8 broken in Microsoft Flight Simulator Settings). After one minute or at 13 or 31 minutes had passed, the second change from 4/8 broken to 5/8 broken occurred. At 14 or 32 minutes into the flight the third change from 5/8 broken to 7/8 broken with a visibility of 3 miles was implemented. In total, weather degraded three times with one minute intervals occurring between each change. The one minute intervals were done to mimic gradually changing weather that often occurs in a real world flying situations.

Table 2: Table of the Initial Weather Specifications and Changes

Weather Specifications	Initial Weather (Start of Flight)	First Change (12 or 30 mins)	Second Change (13 or 31 mins)	Third Change (14 or 32 mins)
Ceiling: 15,000/base	/8,000 scattered	/5,000 broken	/5,000 broken	/5,000 broken
Microsoft Ceiling Setting	Scattered 4/8	Broken 5/8	Broken 6/8	Broken 7/8
Visibility	10 miles	5 miles	5 miles	3 miles
Temperature (dew point)	23 (15)	23 (15)	23 (15)	23 (15)
Wind: altitude, direction, speed	6000, 290, 13	6000, 290, 13	6000, 290, 13	6000, 290, 13

Regardless of condition, the scenarios called for two more weather degradations before reaching Gainesville. The second to last occurred as the pilot was passing over Palatka and the last was 10 miles from the Gainesville airport. The weather over Palatka was degraded from the third change by setting rain to moderate and increasing visibility to 5 miles and ceiling to 7000 overcast (see Table 3). Some of the WL pilots flew over Palatka before the initial weather changes allotted to occur at 30 minutes. These pilots did not receive the changes indicated to occur over Palatka and received the initial changes after 30 minutes has passed. If these WL pilots continued to Gainesville after receiving the weather at 30 minutes, they received the weather changes 10 miles from

Gainesville with moderate levels of rain being implemented here. All of the pilots that received the initial three weather changes received the weather changes over Palatka. Other than the changes made to some of the WL pilots, all other weather changes were consistent across conditions. Weather rarely changes immediately and stays constant for period of time. In effort to create realistic weather conditions, the weather in the experiment gradually degraded and changed a total of five times over the entire flight.

Table 3: Table of the Last Two Weather Changes

Weather Specifications	Third Change (14 or 32 mins)	Crossing Palatka	10 Miles from GN
Ceiling: 15,000/base	/5,000 broken	/7000 overcast	/1500 scattered
Microsoft Ceiling Setting	Broken 7/8	Overcast	Scattered 5/8
Visibility	3 miles	5 miles	3 miles
Rain	None	Moderate	Moderate
Temperature (dew point)	23 (15)	23 (15)	23 (15)
Wind: altitude, direction, speed	6000, 290, 13	6000, 290, 13	6000, 290, 13

Procedure

In the first thirty minutes of the experiment, the pilots read and signed the informed consent and filled out the demographic questionnaire. The pilots were assured that their information would be kept confidential and should answer the questionnaires as honestly and accurately as possible. It was also explained that the pilots should not speak with anyone about any information they learned during the session with anyone else. This helped to ensure that other instrument rated pilots could participate without fear of gaining additional information that could affect their performance in the study.

The pilots received a briefing form prior to the flight. The briefing form included information about how to operate the simulator. The pilots were informed that the flight was a “life flight” and that they would be transporting a liver from Daytona Beach to a patient in Gainesville. The reason behind this design was to create a realistic need for the pilots to reach the destination. The pilots were then told that their flight was a VFR flight from Daytona Beach Airport to the Gainesville Airport about 42 minutes away. The requested altitude was indicated at 4500 feet and that their call sign to be used throughout the entire flight was “Riddle Life Flight 321”. The pilots were informed that the military restrictive areas located between Daytona Beach and Gainesville were active and should be avoided. If the pilot was assigned to the extrinsically motivated condition, they received the information about the bonus payment when reaching the Gainesville airport.

The pilots were then instructed that they could spend a few minutes looking over the information and when ready were instructed to get into the simulator. Once in the simulator the pilot was given the sectional and was informed where navigational buttons were located. Some of these buttons included the CDI, OBS, heading bug, VOR navigations, electric trim, and flap switch. The pilot was instructed to put on the headset located in the simulator to communicate with the air traffic controller (ATC) seated directly behind the simulator. The pilots were given as much time as needed to familiarize themselves with the cockpit before starting the flight scenario. Once the pilot put on the headset and programmed the radio stack, ATIS was read by ATC as well as clearance, delivery and tower. Upon completion of these steps the pilot was cleared for takeoff.

Once the pilot initiated takeoff, the stop watch was started to record the time during the flight. The timer was used to record the entire flight time, time to encounter degrading weather (i.e., early/12 minutes or late/30 minutes), one minute intervals at which weather was degraded, and the length of time the pilots penetrated weather (i.e., dependent measure). Based on random assignment, the pilots received degrading weather early or late into the flight. Weather was degraded three times with one minute intervals between each change. Two additional weather changes occurred, one over Palatka and the last weather change 10 miles from Gainesville. The pilots received these changes unless they flew a different flight that did not cross Palatka, flew over Palatka before the initial weather changes occurred, or diverted before these changes could be implemented.

Ten minutes into every flight a "radio failure" occurred. The failure allowed the pilots to hear ATC's calls but made it seem as though ATC could not hear the pilot's calls. The reason behind the radio failure was to prevent the pilots from calling ATC to file an IFR flight plan when degraded weather was encountered. This forced the pilots to make the decision to continue the flight and deliver the liver or divert the flight to a safe location.

The experiment could end in one of following three ways: the pilot could continue flying VFR into degraded weather which eventually turned into IMC reaching the destination, the pilot could crash before reaching the destination, or the pilot could divert from the flight plan and land at an alternative airport. All of the pilots successfully landed the aircraft regardless of whether they continued the flight to the destination or diverted. If the pilot decided to divert from the flight plan, the rater indicated this decision and marked the time at which this action occurred. Once the pilots landed, they were asked to exit the simulator and were instructed to complete the post-experimental questionnaire. After the pilots completed the questionnaires they were told the reason why the study was conducted, received their payment and thanked for their participation.

Results

Exploratory Analysis

The data from the 40 pilots was entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 14.0. The condition to which the pilots were randomly assigned and the length of time each pilot flew into weather was entered into SPSS. The dependent variable was calculated by subtracting the point at which the pilots encountered degraded weather (12 or 30 minutes) from the pilot's diversion time, landing time at the destination in Gainesville, or if the pilots continued past 15 minutes a cutoff point of 15 minutes was implemented to maintain a consistent amount of time the pilots were allowed to fly into weather across the conditions. An exploratory data analysis was conducted on the data to adequately display how motivation and investment influenced the length of time the pilots flew into weather.

As shown in Table 4, the externally motivated (EM) pilots who encountered weather early in the flight flew an average of 12.79 minutes, (*SD* = 4.72), into degraded weather while the EM pilots who encountered degraded weather late in the flight flew 6.96 minutes (*SD* = 5.41). The internally motivated (IM) pilots who encountered degraded weather early in the flight continued into weather for 7.55 minutes, (*SD* = 5.92) and the IM pilots who encountered degraded weather late in the flight continued into weather 8.56 minutes, (*SD* = 5.62). Based on visual inspection of the means, the EM pilots who encountered degraded weather early in the flight continued the longest, while the EM pilots who encountered weather late in the flight continued the shortest amount of time. The two remaining groups continued into weather somewhere in between.

Table 4. Table of the Time into Weather Raw Means (standard deviations)

	Investment: Encountered Degraded Weather	
Motivation	Early (12 minutes)	Late (30 Minutes)
Extrinsic (EM)	12.79 (4.72)	6.96 (5.41)
Intrinsic (IM)	7.55 (5.92)	8.56 (5.62)

Levine's Homogeneity of Variance. Because homogeneity of variance is one of the assumptions of ANOVA and indeed, most parametric tests, Levine's test was used to assess departure from this assumption. The results, $F(3, 36) = 3.496$, p=.025, indicated that the group variances were not sufficiently homogeneous, however the robustness of the ANOVA with respect to the violation of this assumption allows for meaningful results (Howell, 2002).

MANOVA

In order to assess the degree to which experience (i.e., flight hours) related to the independent variables a two-way multivariate analysis of variance was conducted on TAA, VFR, and IFR flight hours. The MANOVA for the three categories of flight hours revealed a significant interaction for weather and motivation, $\lambda\ (3, 34) = 3.82; p = 0.018$. The univariate tests found that the interaction resulted from the relationship between weather and motivation for TAA only, $F(1, 36) = 8.98; p = 0.005$. Since the main focus of this investigation was not flight hours, no simple effects were employed to decompose the interaction, however, TAA was used as a covariate in subsequent analyses to ensure that any systematic effects of TAA on the dependent measure was held constant across the treatment groups.

Individual correlations between VFR, IFR, and TAA hours and the length of time the pilots flew into weather were conducted. No significant differences were found for the correlations of VFR hours, $r(38) = -0.222, p = 0.17$, IFR hours, $r(38) = -0.154, p = 0.342$, and TAA hours, $r(38) = -0.268, p = 0.095$. When these three negative scores are compared, TAA hours resulted in the largest negative score. Even though differences were not significant, the negative correlations indicate that the pilots with fewer flight hours (i.e., experience) continued into weather longer than the pilots that had more hours.

ANCOVA

In order to assess group differences in terms of continued flight into degrading weather, a 2 (internal/external motivation) X 2 (early/late weather) analysis of covariance (ANCOVA) with TAA hours serving as the covariate was conducted. The significant result for TAA hours, $F\,(1, 35) = 6.395, p =0.016$, indicated systematic variation of this factor across the groups supporting the use as a covariate. The ANCOVA revealed a non-significant main effect for weather, $F(1, 35) = 1.357, p = .252$, and a non-significant main effect for motivation, $F\,(1, 35) = 6.908, p = .607$. The non-significant results indicate that no differences existed with respect to weather and motivation.

The non-significant main effects for weather and motivation were modified by a significant interaction between weather and motivation, $F(1, 31) = 9.223, p = .004$ (see Figure 9).

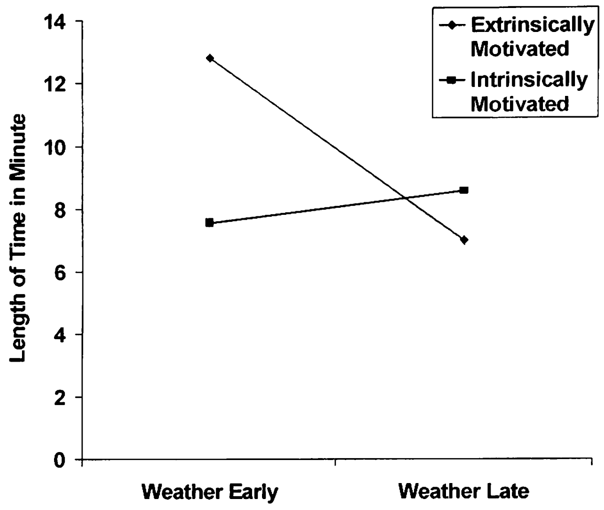

Figure 9: Mean comparisons between conditions

Simple Effects. To verify the mean differences noted in Figure 9, simple effects analyses were conducted to decompose the interaction. The simple effect analyses assessed motivation (extrinsic/intrinsic) at each level of weather (early/late). The analyses revealed that the interaction resulted from the significantly longer persistence of the EM pilots when compared against the IM pilots while encountering weather early in the flight, $F(1, 35) = 7.46, p = .01$. No significant difference was found when the EM pilots were compared against the IM pilots when encountering weather late in the flight, $F(1, 35) = 3.22, p = .081$. This implies that the manipulation of motivation and investment for the pilots who encountered weather late in flight did not have an effect on the length of time the pilots flew into weather. On the other hand, the manipulation of motivation and investment for the pilots who encountered weather early in the flight did have an effect on the length of time the pilots flew into weather.

Kruskal-Wallis

The 19 questions from the FADM/JQ were assessed to isolate specific questions that dealt with in-flight weather-related decision making scenarios. A Kruskal-Wallis analysis was used to analyze the ranking scores on questions 4, 7, 9, 10, 11, 12, 13, and 18. Specifically, the analyses were conducted to identify if a majority of the pilots who continued or diverted ranked any of the options similarly. The Kruskal-Wallis analysis revealed significant differences only on the likelihood rankings for 7b, $H(1) = 12.037, p = .001$, and 18c, $H(1) = 4.364, p = .037$. The significant findings indicated that differences existed in the responses of the pilots that continued and the responses of the pilots that diverted in the experimental session. A frequency count was done to identify how the 40 pilots ranked options 7b and 18c.

For question 7, a situation was described in which the first half of a four hour flight was slightly better than marginal VFR. The pilot departs and reaches a level altitude in VFR conditions and is ready to call in to check with Flight Watch. The pilot expects that while calling Flight Watch they will be asked for their PIREP. Option 7b states that the pilot informs Flight Watch they are to busy and can't take the time to report their PIREP. The significant difference indicates that differences exist on how pilots who continued and the pilots that diverted ranked this option as a likely course of action.

A frequency distribution, (see Figure 10), revealed that a majority of the pilots who diverted ranked 7b as a one and two (i.e., an unlikely choice) while a majority of the pilots that continued ranked 7b as a two (i.e., an unlikely course of action). It should be noted that very few pilots ranked this option as a five or a likely course of action. These frequency counts indicate that a large number of pilots who diverted did not take the time too report their PIREP, while the pilots that continued responded in a similar manner.

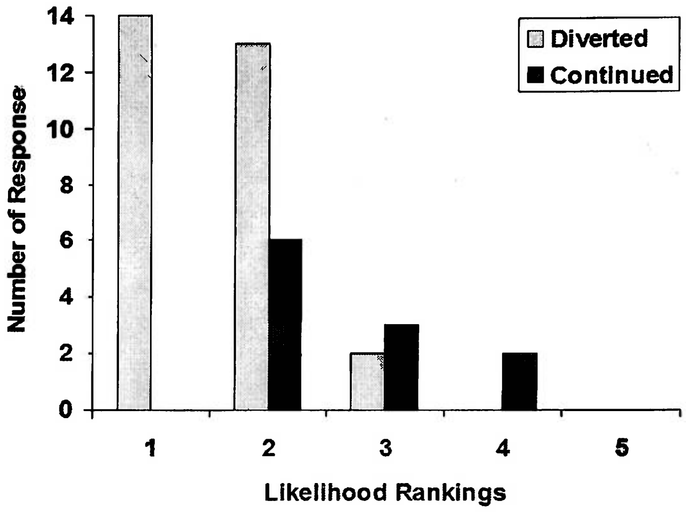

Figure 10. Frequency counts between the pilots that diverted and continued on the likelihood rankings for 7b

Question 18 describes a situation where a pilot receives information from ATIS that the weather is below minimums at the destination. The pilot receives holding instructions while expect further clearance (EFC) is one hour away. The pilot only has an hour and 15 minutes of fuel and the passenger urges the pilot to hold because of a meeting that can not be missed. Option 18c states that the pilot enters the hold and hopes that ATC can fit them in sooner than the EFC time.

The frequency distribution (see Figure 11) for the pilot's rankings revealed that a majority of the pilots who diverted ranked 18c as a two (i.e., an unlikely course of action) or three (i.e., mutually exclusive course of action) with very few pilots ranking this option as a five (i.e., a likely course of action). The pilots that continued ranked 18c as a three (i.e., a mutually exclusive course of action) with five (i.e., a likely course of action) being the next biggest ranking group. This means that a majority of pilots who diverted found the option to hold as an unlikely course of action while the pilots who continued ranked the option to enter the hold more appealing.

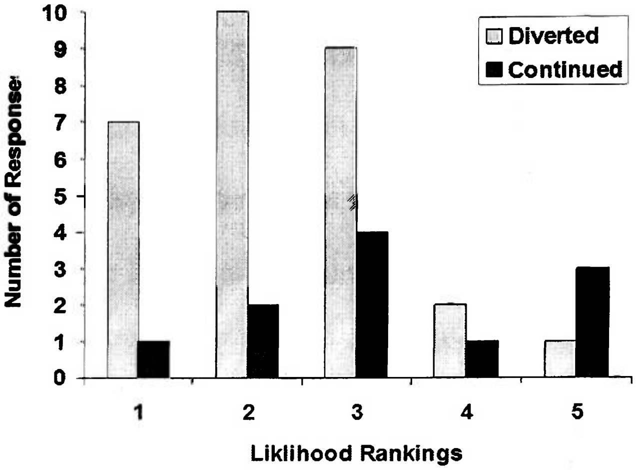

Figure 11. The frequency counts between the pilots that diverted and continued on the likelihood rankings for 18c

Statement of Hypotheses

Hypothesis One. It was hypothesized that a significant main effect for motivation would be found. It was also expected that the pilots who received the financial incentive would fly longer into adverse weather than the pilots in the non-incentive group. This hypothesis was not supported since no significant differences were found in the length of time the pilots flew into weather due to the manipulation of motivation.

Hypothesis Two. It was expected that a significant main effect for investment would be found. It was also expected that the pilots who encountered degraded weather late (30 minutes) into the flight would fly longer into degraded weather than the pilots who encountered weather early (12 minutes) into the flight. The non-significant main effect found for investment did not support this hypothesis and the manipulation of investment did not have an effect.

Hypothesis Three. It was hypothesized that the main effects would be modified by an interaction between investment and motivation. It was expected that a significant difference would be found between the EM and IM pilots who encountered weather early in the flight, while no significant differences were found between the EM pilots and IM pilots who encountered degrading weather late in the flight. It was expected that the EM pilots who encountered weather late would continue the longest while the IM pilots who encountered weather early would continue the shortest amount of time into weather.

This hypothesis was partially supported when the non-significant main effects for investment and motivation were modified by the significant interaction between motivation and investment but the subsequent analyses did not support the remaining hypothesis. Based on the simple effects analysis, the significant results for the EM and IM pilots who encountered weather early and the non-significant findings for the EM and IM pilots who encountered weather late support this hypothesis but the overall findings do not support this hypothesis. The EM pilots that encountered weather early continued into weather the longest while the EM pilot who encountered weather late continued the shortest amount of time into weather. These findings are contrary to what was expected and some reasons exist to why this may be.

Discussion

Many models exist that can be used to explain the decision making process. Two examples discussed in this paper are Slade's (1994) basic overview of decision making and Jensen's (1995) Judgment Model, which has helped researchers understand the mechanisms involved in the decision making process. Decisions are made everyday and can range from easy ones like what color pants to wear, to difficult decisions like whether to continue or divert when encountering degraded weather. Some of the factors that influence the decision making abilities of pilots' include situation assessment, risk perception, motivation, and decision framing. This study focused on motivation and the sunk-cost effect, as a means of understanding why some pilots fly into degraded weather.

The sunk-cost effect claims that pilots who have invested more resources (e.g., time, effort, money) will be more likely to continue flying into degraded weather than pilots who have invested fewer resources. Once a pilot has made an investment in a flight, the potential for losing this investment will increase the likelihood of continuing the flight into degraded weather, even if the situation is unsafe (Kahneman & Tversky, 1984). For example, accident LAX04FA113, presented at the beginning of this paper, supports the sunk-cost effect since the pilot continued the flight through degraded weather resulting in an accident associated with fatalities close to the destination. This accident example along with accident statistics reveal that many GA pilots fly into weather every year and, unfortunately, 75% of weather-related accidents are associated with fatalities (O'Hare & Wiegmann, 2001). It was because of the unforgiving nature of weather-related accidents that this study investigated the role that the sunk-cost effect (i.e., investment) and motivation play in pilots' decision making abilities when encountering degraded weather. The results from this study do not support the sunk-cost effect and some reasons to explain these results include flight experience, the situation assessment hypothesis, differences in perceptual processing, and cognitive anchoring.

One explanation for why some pilots fly into weather is due to differences that exist in flight experience (Goh & Wiegmann, 2002b). Experience levels or flight hours were investigated to see if a relationship existed between motivation, investment, and the length of time the pilots flew into degraded weather. Specifically, VFR, IFR, and TAA hours, were investigated and the significant difference found for TAA hours indicated a relationship between experience levels in TAA and the likelihood of continuing into degraded weather conditions. The individual correlations between VFR, IFR, and TAA while not significant, did reveal a negative linear relationship for all three variables relative to flight experience. Similar to what Wiegmann, Goh, and O'Hare (2002) found, the negative correlations indicate that the pilots who had more flight hours flew less time into weather while the pilots who had fewer flight hours flew longer into weather. This leads to the assumption that flight experience plays a role in the length of time the pilots flew into weather. Furthermore, the significant difference in TAA hours and the lack of significant differences for VFR and IFR hours indicates that qualitative differences in flight training experiences may have played a role in whether or not pilots flew into weather. Unsure of what exact differences exist in pilots' experience levels lend some pilots to fly longer into degraded weather but differences exist and further research is needed to fully understand this relationship. The significant differences in TAA hours between the groups indicated the need to include this variable in the principle analysis.

Because TAA hours played a role in the length of time pilots flew into weather, an ANCOVA was conducted with TAA as a covariate, allowing for the assessment of motivation and timing of weather, absent the effects of TAA. The non-significant effect for motivation indicated that motivation in this study did not have an effect on the length of time the pilots flew into weather. Individual differences could explain one reason why no differences were found for motivation. The 20 dollar bonus payment may not have been enough of a motivator for the externally motivated pilots to continue into degraded weather longer than the internally motivated pilots.

Based on what the sunk-cost effect claims, it was expected that the pilots who encountered weather late in a flight invested more resources than pilots who encountered weather early in a flight. Further, it was anticipated that the EM pilots who encountered weather late in the flight would continue longer into degraded weather, while the IM pilots who encountered weather early in the flight would continue a shorter amount of time. The results from this study found that the pilots that received weather early in the flight continued longer into degraded weather than the pilots that received weather late in the flight. The significant simple effects analysis revealed that the EM pilots continued significantly longer than the IM pilot who encountered weather early in the flight, while not differences were found in the length of time the EM and IM pilot flew into weather when encountering weather late in the flight. A study conducted by Wiegmann, Goh and O'Hare (2001) and the results from this study support these findings. Wiegmann, Goh and O'Hare (2001) in a similar study instructed a group of pilots to fly a cross-country flight where half received degrading weather early while the other half received degrading weather late. The results from this study revealed that the pilots that encountered weather early in the flight continued longer and farther into to weather than the pilots that encountered weather late in the flight. These results do not support the claims made by the sunk-cost effect, but are supported by the situation assessment hypothesis, differences in perceptual processing, decision making, and cognitive anchoring.

The situation assessment hypothesis states that pilots who encounter weather early in the flight continue into weather because they do not accurately assess degrading weather. This inaccurate assessment of degrading weather leads pilots to fly into weather without realizing they are doing so (Wiegmann, Goh, & O'Hare, 2002). Just as the sunk-cost effect is a possible explanation for why pilots fly into degrading weather, the situation assessment hypothesis and the weather location effect are possible explanations supported by the results found in this study of why pilots fly into weather.

It is understood that pilots with more experience should be more effective and efficient in identifying degrading weather than pilots with less experience. Burian, Orasanu, and Hitt (2000) found that pilots with less experience continued into weather longer because they did not "trust" their perception of degrading weather and continued flying "blindly" into degrading weather. In addition to experience in assessing degrading weather, the location at which pilots encounter weather, the weather location effect, influences the length of time pilots fly into weather. The degrading weather the pilots encountered early in the flight contradicts what the pilots expected weather to be like based upon reports received prior to takeoff. Because of this contradiction, the pilots "look around" to resolve the disparity between the weather report previously obtained and the degrading weather encountering early in the flight. This behavior to "look around" may lead the pilots who encounter weather early in the flight to fly longer into weather than the pilots who encounter weather late in the flight. The pilots that encounter weather later in the flight assume that the weather report obtained before takeoff is outdated and make their decision based on the weather condition currently experiencing (Wiegmann, Goh, & O'Hare, 2002). The ability for the pilots to realize that the weather report is outdated may contribute to less flight time into degrading weather than the pilots who encounter weather early in the flight.

In addition to the situation assessment hypothesis, differences in perceptual processes could explain why pilots who encountered weather early in the flight continued into weather longer than the pilots who encountered weather late in the flight. It is easier for pilots to perceive weather changes after a long period of exposure to consistent weather than it is for pilots who have been exposed to consistent weather for a shorter period of time. The pilots who encountered weather late in the flight were exposed to a long period of constant weather which allowed the pilots to notice changes in degrading weather quicker. On the other hand, the pilots who encountered weather early in the flight had a shorter period of consistent weather to compare against the weather changes. The less time the pilots are exposed to the weather conditions before the weather changes occur may contribute to longer flight into degrading weather when deciding if the weather conditions are degrading enough to divert (Wiegmann, Goh, & O'Hare, 2002).

Differences in the pilots' decision making may contribute to flight into degrading weather. Specifically, the differences that existed in the length of time the pilots who continued and the pilots who diverted can be attributed to differences in-flight weather-related decision making. To investigate whether differences were present between the pilots that continued and diverted, the likelihood rankings for the weather-related scripted scenarios were analyzed from the FADM/JQ.

For the responses on 7b, overall, the pilots ranked the option of telling Flight Watch that they are too busy to give them their PIREP in marginal VFR conditions as an unlikely course of action. More of the pilots that diverted ranked this option as an unlikely course of action while some of the pilots that continue ranked this option as a likely course of action. When the pilots encountered degrading weather, the pilots that continued may have been more focused on what was going on in their environment and trying to decide whether to continue and did not have the time to inform Flight Watch of their PIREP. The pilots that diverted had already made the decision and were more likely to give their PIREP to Flight Watch.

In the responses for 18c, the pilots that diverted ranked the option to enter the hold in below weather minimums in hopes to land before the EFC time as an unlikely course of action. With the pilots that continued, this response was ranked somewhere in the middle between an unlikely course of action and a likely course of action. Furthermore, more pilots that continued ranked this option as a likely course of action than the pilots that diverted and more pilots that diverted ranked this option as an unlikely course of action than the pilots that continued. These responses indicated that the pilots who diverted were less likely to enter a hold and wait in compromising conditions than the pilots that continued. The responses to these items indicate differences in weather-related decision making while supporting the outcomes of this investigation.

For pilots to make the best possible decision under uncertainty, an accurate assessment of the situation is required usually requiring the pilots to spend time assessing the situation before making the decision. Any information the pilot gains prior to making a decision may bias his or her decision in favor of that information. Madhavan and

Wiegmann (2005) label this behavior as cognitive anchoring which has an effect on a person's ability to make decisions under uncertainty. For example, when a person is asked to estimate if Daytona Beach, Florida has less or more than 50,000 people and then asked to estimate the actual number of people living in Daytona Beach. Their estimation of the actual number of people living in Daytona Beach is closely related or "anchored" to the original estimation on whether they though there were less than or more than 50,000 people (Epley & Gilovich, 2006). In this study, the pilots that received weather early in the flight may have continued into weather longer than those who received weather late in the flight because of cognitive anchoring.

How cognitive anchoring incorporates into Jensen's (1995) Judgment Model can help explain why pilots in this study who encountered weather early in the flight continued longer into weather than the pilots who encountered weather late in the flight. Pilots gain information and create a hypothesis about the weather condition for the flight from the weather report obtained prior to takeoff. The pilots use the weather information obtained from the weather report as an "anchor" to make comparative assessments of the weather conditions throughout the entire flight, the problem vigil stage. Specifically, when degrading weather is encountered early in the flight the pilots are biased towards the initial hypothesis or "anchor" established from the weather report. Because of this, the pilots do not easily or quickly accept an alternative "anchor", the degraded weather, but rather have a stronger tendency to favor the original anchor, the weather report. This may lead pilots to fly into weather longer until the "anchor" is changed or according to the situation assessment hypothesis the disparity is resolved. The pilots who encounter weather late in the flight are less influenced by the "anchor" of the weather report because it is outdated and are more open to changing this "anchor". Thus, how pilots are cognitively "anchored" may influence the length of time pilots fly into weather before diverting. This may be compounded by that fact that pilots who encountered weather early in the flight had more time to evaluate the situation before pressed to make the decision, possibly leading to longer flight into degraded weather. The pilots who received weather late in the flight were required to make the decision to continue or divert much quicker than the pilots who received weather early in the flight (Goh and Wiegmann, 2001a).

The limitations of this study included the use of a simulator, the familiarity with the flight route, inconsistencies with the weather specifications and how the equipment could display them, and the lack of influence the bonus payment had in the external motivation condition. This study was conducted in a flight simulator rather than in an actual aircraft and differences in the pilots' performance could exist between these two environments. One of the risks with conducting research in a simulator is the possibility that the pilots may have been "performing" for the investigator. This may not have been the case since the purpose of the study was concealed until after the flight scenario was completed, but this issue must not be dismissed. Since all the pilots were from Daytona Beach the flight route from Daytona Beach to Gainesville may have been a familiar one. Since the flight was in Florida the terrain was very flat allowing the pilots to descend to around 1500 feet and continue flying to Gainesville. The combination of familiarity with the flight and the level terrain may have had an influence on the number of pilots that continued the entire way to the destination. One problem with the equipment is how the weather specifications indicated in Microsoft Flight Simulator were not projected exactly as entered. Weather was perceived as better than what was actually indicated on the control panel and presented in the weather manipulating section of Microsoft Flight Simulator. Last, the bonus payment used for the extrinsic motivation condition was not effective in motivating the pilots to continue to the destination. Some of the pilots may have viewed the payment as insufficient to compromise the safety of the flight. Even with these limitations, some of the pilots continued through degraded weather indicating the weather was ambiguous enough the allow them to continue, while some of the pilots diverted during the experiment indicating the weather conditions were bad enough to cause these pilots to divert.

Conclusion

The statistics support that weather-related accidents are one of GA's primary safety concerns, especially since many weather-related accidents are associated with fatalities. Many factors encourage pilots to fly into degraded weather and the purpose of this study was to assess how motivation and investment relate to the length of time pilots fly into degraded weather. While the intent was to frame the investigation within the sunk-cost effect, the findings point in another direction. Originally it was thought that the pilots who encountered weather late in the flight would continue the longest into degraded weather, but instead, through this study it was found that the pilots who received weather early in the flight continued longer into degraded weather than the pilots who encountered weather later. To understand why pilots fly into weather, decisions made in weather scenarios were analyzed. The decision making analysis was conducted to better understand how pilots make decisions to continue or divert into degraded weather, but unfortunately, the findings do not fully explain why pilots fly into weather. It may prove beneficial to research what motivates pilots to make the decision to fly into weather. Some motivational factors could include the situation assessment hypothesis, perceptual processing differences, and differences in cognitive anchoring. In addition to understanding how pilots perceive degrading weather (situation assessment hypothesis) or where weather is encountered (weather location effect), the way in which pilots view the decision to continue or divert against information he or she already knows, (cognitive anchoring) may influence the length of time pilots fly into degraded weather. With better understanding of these factors it may be possible to identify effective interventions to reduce the number of pilots that fly into degraded weather with hopes of reducing the accidents and fatality numbers associated with weather-related accidents.

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Appendix A: Informed Consent Form

I consent to participating in the research project entitled:
Flight Research for ADS-B Implementation

The principle investigator of the study is:
Jon French x 386-226-6384 frenc70f@erau.edu

The study will focus on the difference between relatively low flight time and relatively high flight time pilots in their instrument scans, particularly as it relates to glass instrument flight. It will utilize the assets of the technically advanced aircraft performance (TAAP) lab (LB374) simulators to establish the procedures and metrics that will be transferred to the more sophisticated Flight Training Devices and then to actual flight (Phase II). Thus, the study will consider, transfer of training from flight simulators to FTD and actual flight.

I will be expected to arrive at my scheduled time over the 4 days in which I am a participant in the evaluation of instrument scan. The total time I will be needed should not exceed 2 hours the first day and 1.5 hours the 2-4th day. I will be asked to fly a C-182 simulator for about 30-50 minutes and to fill out questionnaires for the remaining time each day. All my results will be kept confidential and will not be associated with my name. I will be paid $150 for my participation in the study.

The individual above, or their research assistants, have explained the purpose of the study, the procedures to be followed, and the expected duration of my participation. Possible benefits of the study have been described, as have alternative procedures, if such procedures are applicable and available.

I WILL NOT DISCUSS THE METHODS OR CONDITIONS I EXPERIENCE WITH OTHER PILOTS WHO MIGHT THEMSELVES BECOME PARTICIPANTS AS THIS COULD INFLUENCE THEIR PERFORMANCE ADVERSELY.

I acknowledge that I have had the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that I am free to withdraw consent at any time and to discontinue participation in the study without prejudice to me.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Name (please print): ____________________ Date : __________
(Participant)

Signed: ______________________________
(Participant)

Signed: ______________________________
(Researcher/Assistant)

Appendix B: Demographic Data Flight Performance I

DDFP-I

Demographics Data Flight Performance I

Thank you for participating in this evaluation. This form asks questions about your piloting and computer experience. We will use this information to determine any factors that might explain your proficiency in technologically advanced aircraft (TAA). Please answer the following questions:

1. Name: ____________________
2. Sex: M F
3. Age: ______
4. Flight Licenses and certificates achieved:
   (List each, the approximate date achieved, and years held, and if current. Use additional paper if more room is needed.)

License/Certificate	**Date achieved**	**Years held**	**Current? Yes/NO**

5. Please list any recurrency training you've received and the date.

6. Please list the types of aircraft you've flown general aviation and commercial (FAA categories), and approximate dates and hours in each.

7. Please list the types of military aircraft you've flown and approximate dates and hours in each.

8. Approximate number of hours flown in VFR ___________

9. Approximate number of hours flown in IFR ____________

10. Approximate number of hours flown in TAA or (Technologically advanced aircraft; i.e., "glass cockpit") like the Garmin 1000. _____________

11. What types of glass instruments have you flown with?

12. List the airplanes you own or have owned (partnership or sole owner).

Appendix C: Federal Aeronautical Decision Making / Judgment Questionnaire

DM/JQ:

Adapted From: Driskill, W.E., Weissmuller, J.J., Quebe, J.C., Hand, D.K. and Hunter, D.R (1998). Evaluating the decision making skills of general aviation pilots. DOT/FAA/AM-98/7

This questionnaire is designed to assess pilot decision making and judgment. Please read each of the following descriptions and indicate the risk of each option. *Assume the aircraft is a TAA.*

1. You are flying an "Angel Flight" with a nurse and non-critical child patient to meet an ambulance at a downtown regional airport. You filed VFR it is 11:00 P.M. on a clear night when at 60 NM out you notice the ammeter reading zero and correctly deduce the alternator has failed. Your best guess is that you have from 15 to 30 minutes of battery power remaining. How likely are you to do the following?

	Highly Unlikely				Highly Likely
a. Declare an emergency, turn off all electrical systems except for NAVCOM and transponder and continue to the Regional Airport as planned.	1	2	3	4	5
b. Declare an emergency and divert to the Planter's County Airport which is clearly visible at 2 o'clock, 7 NM.	1	2	3	4	5
c. Declare an emergency, turn off all electrical systems except for 1 NAVCOM, instrument panel lights intercom and transponder and divert to the Southside Business Airport which is 40 NM straight ahead.	1	2	3	4	5
d. Declare art emergency, turn off all electrical systems except for 1 NAVCOM, instrument panel light intercom and transponder and divert to Draper Air Force Base which is 10 o'clock at 32 NM.	1	2	3	4	5

Airport	**Runway**	**24hr Tower**	**ARSA**	**Lighted Runway**	**Telephone Available**	**Maintenance**
Regional	8800x150 7753x150	Yes	Yes	Yes	Yes	24 hrs
Planters County	3200x75	No	No	Yes	Yes	0700-1800
Southside Business	4835x100 4129x100	Yes	Yes	Yes	Yes	0700-1800
Draper AFB	11500x300	Yes	No	Yes	Yes	None

2. You are preparing to enter the VFR traffic pattern at the Regional Airport and hear the tower report winds from 280 at 15 knots ATC is vectoring traffic to the primary 8800 ft runways 35. A Piper Cherokee asks to use the 7753x150 runway 27. The Cherokee is told the runway is not active, but to you it looks OK. You decide to:

	Highly Unlikely				Highly Likely
a. Accept clearance to runway 35 and follow the traffic.	1	2	3	4	5
b. Ask to use runway 27.	1	2	3	4	5
c. Insist on using runway 27 stating that the crosswinds are unsafe for you to use runway 35.	1	2	3	4	5
d. Divert to the Southside Business Airport where the runway is almost directly aligned with the wind.	1	2	3	4	5

3. To prepare for when marginal VFR weather makes it difficult to return to your home airfield (uncontrolled), you practice in VFR conditions:

	Highly Unlikely				Highly Likely
a. An unofficial locally devised arrival to the pattern.	1	2	3	4	5
b. Have devised your own arrival route to the pattern or runway.	1	2	3	4	5
c. Practice a published IFR approach.	1	2	3	4	5
d. Don't do anything.	1	2	3	4	5

4. While en route you want to find out what is going on along the weather pattern you observe ahead. You decide to:

	Highly Unlikely				Highly Likely
a. Call an airport tower below and ask.	1	2	3	4	5
b. Call FSS and ask.	1	2	3	4	5
c. Find the ATC frequency, call and ask them.	1	2	3	4	5
d. Identify an airplane ahead and ask for a PIREP.	1	2	3	4	5

5. The weather is stuck in the summertime high mode with clear mornings, hazy afternoons. puffy clouds scattered at 5500 feet AGL with visibility at 7 miles or more. When you go cross country in these weather conditions you usually decide to:

	Highly Unlikely				Highly Likely
a. Don't file but fly airways.	1	2	3	4	5
b. File VFR and stay off airways.	1	2	3	4	5
c. File IFR	1	2	3	4	5
d. File VFR on airways as much as possible.	1	2	3	4	5

6. Take-off and en route weather arc VFR with a dry line scheduled through your destination about your ETA. It may push some thunderstorms ahead of it so your weather briefing ends with "VFR flight is not recommended" There are several good alternate airfields along the route of flight and beyond your destination. You decide to:

	Highly Unlikely				Highly Likely
a. File IFR and utilize weather radar on board	1	2	3	4	5
b. File VFR to an airport short of your destination, land and let any weather pass over.	1	2	3	4	5
c. Delay your departure until the "VFR flight is not recommended" statement is removed from the forecast.	1	2	3	4	5
d. File VFR to your destination.	1	2	3	4	5

7. The weather for departure and the first half of your four hour cross country was slightly better than marginal VFR You made it off and have leveled at cruise altitude in VFR conditions and are preparing to cheek in with Flight Watch You suspect they will ask you for a PIREP to check their forecast. You decide to:

	Highly Unlikely				Highly Likely
a. Calculate your drift, determine the winds, make note of the cloud cover and types, and note the OAT to be ready when they ask.	1	2	3	4	5
b. Beg off- telling them you have your hands full and can't take the time.	1	2	3	4	5
c. Expect to give at least your position, cloud bases and tops, visibility and relate any deviations between what you saw and what was forecast.	1	2	3	4	5
d. Prepare to either confirm the accuracy of their forecast or tell of the observable differences.	1	2	3	4	5

8. You have planned a four plus hour cross-country and the weather could easily force you into rather undesirable routes which would take you over rough and desolate country. To match the best weather and route combination, you decide to:

	Highly Unlikely				Highly Likely
a. Select the route with which you feel the most comfortable and have the weather forecaster give you the forecast and if VFR is not recommended, repeat this process until you have a VFR route.	1	2	3	4	5
b. Tell the forecaster your departure point, destination and have him select the best route.	1	2	3	4	5
c. Give the forecaster three routes and have him give you the weather for each then you decide.	1	2	3	4	5
d. Delay the flight until you get VFR weather over the primary route.	1	2	3	4	5

9. Three of your closest friends have bought you a choice ticket and are paying for you to rent this airplane and fly the four of you the 180 miles up to the university in the morning for the "BIG" early afternoon football game, then back in the early evening. Another friend will meet you at the college Airport and drive all of you to the game and back. Departure weather was overcast 3000 ft ceiling with 5 miles and light haze with temperatures in the 60s. Pilots flying the same route reported enroute weather as occasional 1500 ft ceilings with 3 miles visibility and scattered showers. The College Airport is clear with bright sunshine. Forty-five miles from the College Airport you have descended to 1000 feet staying just below the ceilings and encounter rain dropping visibility to under 3 miles. The terrain is flat farmland with no published obstacles above 250 ft tall. You decide to:

	Highly Unlikely				Highly Likely
a. Remain under the clouds, keep visual contact with the ground and scoot through.	1	2	3	4	5
b. Do a 180 and return home.	1	2	3	4	5
c. Divert to the Madison County Airport located at 7 o'clock 50 NM and wait for the worst weather to pass.	1	2	3	4	5
d. Put it to a vote.	1	2	3	4	5

Airport	Runway	Tower	ARSA	Lighted Runway	Telephone Available	Maintenance
college Airport	5000x100 4099x100	24 Hrs	No	Yes	Yes	24 hrs
Madison County Airport	3800x75	None	No	Yes	Yes	None

10. You are halfway in a two-hour late evening flight from the Regional Airport cruising at 4500 feet over a route with an MEA of 1500 feet. The weather has been clear as forecast when without any warning you find yourself in a cloud. You are not instrument rated. You decide to:

	Highly Unlikely				Highly Likely
a. Continue straight ahead for a while and see what happens.	1	2	3	4	5
b. Make a 180-degree level turn and get out.	1	2	3	4	5
c. Start a wings level shallow descent to get under it.	1	2	3	4	5
d. Start a wings level climb to get on top.	1	2	3	4	5

11. It had rained all day, but the font pushed south of you and cleared the skies. You are out with two friends on a sight seeing trip to the hills 40 miles away and plan to be back before dark. With sunset still an hour away you notice ground fog beginning to form. You decide to:

	Highly Unlikely				Highly Likely
a. Apply full power and race back to the home Airport.	1	2	3	4	5
b. Call Flight Watch and cruise back home.	1	2	3	4	5
c. Call on your home airfield's CATF to see if anyone is there and can tell you what the weather is doing.	1	2	3	4	5
d. Go directly to an Airport you know is closer than your home Airport, land and find out what the weather is doing.	1	2	3	4	5

12. You are VFR at 5500' MSL, in your new SR22, completed an instrument proficiency check two years ago, have three actual instrument approaches and two simulated instrument approaches in the past six calendar months, holding procedures two months ago, and practiced intercepting and tracking courses this month. You inadvertently enter IMC.

	Highly Unlikely				Highly Likely
a. Contact center and request an IFR clearance and continue to your planned destination.	1	2	3	4	5
b. Enter a 30° bank turn to make a 180° heading change to exit IMC conductions.	1	2	3	4	5
c. Establish straight and level flight, engage the autopilot to hold Heading and Altitude, reset the Heading to initiate 180° turn.	1	2	3	4	5
d. Contact center and request an IFR clearance and request a 180° heading change to exit IMC conductions.	1	2	3	4	5

13. You are VFR at 7500'MSL, in your SR22, returning to Duluth for a recurrent training course, proceeding GPS direct from KGFK (Grand Forks, ND) to KDLH (Duluth Intl) with vectors to ILS09 (PYKLA transition). 60nm west of Duluth you see a line of thunderstorm running from just south of your route of flight toward the northeast moving northeast. You disengage the autopilot and turn to a heading of 130° to maneuver to the south of the thunderstorms, after 15 minutes ATC advises you that a thunderstorm is moved toward Duluth from the southwest.

	Highly Unlikely				Highly Likely
a. Continue on you current heading for another 10 miles and then proceed direct to PYKLA and hold until the thunderstorm is out of the Duluth area.	1	2	3	4	5
b. Engage autopilot, select nearest airport page on your GNS430, select KGPZ and search for needed information on Grand Rapids, MN and select an available approach. Choose and program GNS430 for coupled approach into KGPZ.	1	2	3	4	5
c. Press the Direct function on your GNS430, enter KGPZ, turn the airplane to the DTK course displayed, once established inbound to KGPZ, press PROC and select an approach to Grand Rapids, MN.	1	2	3	4	5
d. Engage autopilot, select nearest airport page on your GNS430, select desired airport, select Direct function to that airport, search for needed information and approach options, program approach, select, and activate appropriate leg.	1	2	3	4	5

14. You are IFR proceeding direct to PYKLA (FAF for the ILS rwy 09 at KDLH) with the autopilot on with NAV and ALT functions on and you have GPS2 set in PFD Nav Source when the PDF fails.

	Highly Unlikely				Highly Likely
a. Regain aircraft control using the backup instruments, turn off the autopilot, and declare an emergency and request radar vectors to PYKLA from Minneapolis Cntr.	1	2	3	4	5
b. Regain aircraft control using the backup instruments, turn off the autopilot, and request radar vectors to PYKLA from Minneapolis Cntr. Select desired approach and appropriate VOR/LOC frequencies.	1	2	3	4	5
c. Regain aircraft control using the backup instruments, select NAV page 1 for course guidance to PYKLA on GPS2, select FPL, PYKLA, and Direct on GPS1 and activate, select AP, NAV, ALT on the autopilot, advise Minneapolis Cntr you have lost your primary flight instruments, now program GPS1 for desired approach and appropriate VOR/LOC frequencies.	1	2	3	4	5
d. Regain aircraft control using the backup instruments, select Direct on GPS1, enter PYKLA and activate, select AP, NAV, ALT on the autopilot, advise Minneapolis Cntr you have lost your primary flight instruments, now program GPS1 with desired approach and appropriate VOR/LOC frequencies.	1	2	3	4	5

15. You are IMC on an IFR flight to Duluth, when the attitude data is replaced with a large red X, the Wind vector data is replaced with dashes, and heading data is replaced with a large red X. You correctly identify the PFD is not receiving valid attitude and heading data.

	Highly Unlikely				Highly Likely
a. Use your back-up instruments for attitude and heading for the remainder of the flight, use the MFD to navigate to VMC conditions, and land at an airport 10 miles from your planned destination.	1	2	3	4	5
b. Use your back-up instruments for attitude and heading for the remainder of the flight, use your GPS1 to navigate to your destination, and fly the GPS21 approach.	1	2	3	4	5
c. Use your back-up instruments for attitude and heading for the remainder of the flight, use the GPS1 or GPS2 to navigate to VMC conditions, and land at the nearest airport.	1	2	3	4	5
d. Use your back-up instruments for attitude and heading for the remainder of the flight, use the GPS1 to navigate to VMC conditions, select the GPSS mode and autopilot, and land at the nearest VMC airport.	1	2	3	4	5

16. You are IMC on an IFR flight to Duluth, when the heading data is replaced with a large red X and the Wind vector data is replaced with dashes. You correctly identify the PFD is not receiving valid heading data.

	Highly Unlikely				Highly Likely
a. Use your back-up instruments for heading for the remainder of the flight, use the GPS1 to navigate to your planned destination, select the GPSS mode and autopilot, and land using the desired approach.	1	2	3	4	5
b. Use your back-up instruments for heading for the remainder of the flight, use the MFD to navigate to VMC conditions, and land at nearest VMC airport.	1	2	3	4	5
c. Use your back-up instruments for heading for the remainder of the flight, use your GPS2 to navigate to your destination, and fly the GPS21 approach.	1	2	3	4	5
d. Use your back-up instruments for heading for the remainder of the flight, use the GPS1 or GPS2 to navigate to VMC conditions, and land at the nearest airport.	1	2	3	4	5

17. You just departed Colorado Springs to the West. You are fully loaded and in solid IMC with freezing drizzle. As you climb ATC gives you a vector to intercept the airway and maintain 7,000 for traffic. On reaching altitude you are concerned about the rising terrain. You call departure control and ask when you can expect to climb. There is no response. Anti-Ice System has been on since take off.

	Highly Unlikely				Highly Likely
a. Switch on the TKS de-ice system, squawk 7600, and continue as per your flight plan.	1	2	3	4	5
b. Declare an emergency and return to Colorado Springs.	1	2	3	4	5
c. Trouble-shoot the radio	1	2	3	4	5
d. Squawk 7700 and divert to your alternate.	1	2	3	4	5
e. Switch on the TKS de-ice system and divert to your alternate.	1	2	3	4	5

18. ATIS is reporting below minimums at your destination and you are given holding instructions with an EFC time one hour away. You estimate that you have fuel for one hour and 15 minutes on board. Your passenger insists that you hold as long as you can because he has an appointment that he cannot afford to miss.

	Highly Unlikely				Highly Likely
a. Ask ATC for priority.	1	2	3	4	5
b. Call Flight Watch on 122.0 for additional weather in the area before making any decision.	1	2	3	4	5
c. Enter the hold and hope that ATC can work you in sooner than the EFC time.	1	2	3	4	5
d. Request clearance to your alternate	1	2	3	4	5

19. After holding for 15 minutes you elect to proceed to your alternate, which is 45 minutes away and is reporting VMC. You receive a clearance and depart the hold. ATC calls you 15 minutes after you leave the hold to tell you that Approach has an open slot and could take you now if you would like to return.

	Highly Unlikely				Highly Likely
a. You accept the offer and are given a vector for the Approach.	1	2	3	4	5
b. You are cutting it too close and elect to proceed to your alternate	1	2	3	4	5
c. You ask for vectors to a closer airport.	1	2	3	4	5
d. You ask ATC to stand-by while you review the situation and your status before making a final decision.	1	2	3	4	5

Appendix D: Early Weather Scenario

KDAB-KGNV VFR
42 minute flight and weather was encountered 12 minutes into flight

Simulator Settings:
MFD declutter -2
TOPO: OFF
TERRAIN: ON
SET PFD NAV to NAV1
360 HSI
DME: ON
BRG1: ON
SET ENGINE DISPLAY ON MFD

The investigator briefed the participant as follows:

1. You are departing KDAB on a VFR flight to KGNV. You are delivering organs from Halifax hospital, to the University of Florida for a liver transplant.
2. You have planned to go VFR at 4500 (see page 3) feet with flight following. The forecasted weather along the route is VFR. Your call sign is "Riddle Life Flight 321".
3. You are unable to program anything on neither the MFD nor the PFD but you can use the VOR navigation aides.
4. A sectional of Jacksonville will be provided to you in the simulator.

Departure time 1400z
KDAB 011353Z 29013KT 10SM SCT080 23/15 A29.92
KGNV 011353Z 21012KT 9SM SCT012 BKN070 23/21 A29.92

Initial Conditions:
Aircraft running on Runway 25 at KDAB
Weather set to match ATIS at KDAB

Daytona Beach ATIS information:
KDAB ATIS information Alpha
1353 Zulu Observation
Wind 290 at 13
Visibility 10
Ceiling 8000 scattered
Temperature 23, dew point 15
Altimeter 29.92
Landing and departing runways 25R and 25L
Contact clearance delivery on 119.3 prior to taxi
Advise on initial contact you have information Alpha

Riddle Life Flight 321, Daytona Beach Clearance. Maintain VFR at or below 3000
Departure Frequency 125.8, squawk 1234

Riddle Life Flight 321, runway 25R. Maintain runway heading. Cleared for takeoff.

Start timer to measure total flight time and time of weather *events.*

Passing 800 feet--- Riddle Life Flight 321, turn right heading 290, contact departure.

Riddle Life Flight 321, radar contact. Climb to requested altitude, resume own navigation to Gainesville.

10 minutes after takeoff

Riddle Life Flight 321, contact Jacksonville center on 125.30

Riddle Life Flight, roger radar contact. Maintain VFR proceed to Gainesville.

We are now simulating radio transmitter failure. When the participant makes radio calls to ATC the person acting like ATC will ignore these calls, but continue to make radio transmissions to other traffic.

Make random radio transmissions to other traffic throughout the rest of the flight.

Subject recognizes lost communications after minutes ________ MIN

Gradual degradation of weather:
1. 12 minutes after departure lower in-flight visibility to 5 miles in haze and ceiling to 5000 (5/8) broken cloud base
2. 13 minutes after departure change ceiling at from 5000 (5/8) broken cloud base to 5000 (6/8) broken cloud base.
3. 14 minutes after departure lower in-flight visibility to 3 miles and ceiling to 5000 (7/8) broken cloud base.

ATIS only receivable after passing Palatka (28J)

He should be about 25 miles or less from GNV when he calls for ATIS.
Once pilot dials in ATIS 127.15 you can make this reading.

KGNV ATIS
Information Bravo
1443 Zulu Special observation
Wind 290 at 13
Visibility 4BR, -SHRA SAY 4mile visibility and mist and for Shra SAY light rain and showers.
Ceiling 1500 Broken. 7000 Overcast
Temperature 23, dew point 23
Altimeter 29.87
Landing and departing runway 29
Advise on initial contact you have information Bravo.

Weather change when passing over Palatka:

1. Increase in-flight visibility to 5 miles
2. Change ceiling from 5000 (7/8) broken to 7000 overcast.
3. Set rain to moderate.

Weather change 10 miles from Gainesville:

1. Add clouds at 1500 scattered.
2. Lower visibility to 3 miles.

Continued:
The participant did not divert and landed at Gainesville __________ minutes after takeoff

Diverted:
The participant diverted __________ minutes after takeoff.

Appendix E: Late Weather Scenario

KDAB-KGNV VFR
42 minute flight and weather was encountered 30 minutes into flight

Simulator Settings:
MFD declutter -2
TOPO: OFF
TERRAIN: ON
SET PFD NAV to NAV1
360 HSI
DME: ON
BRG1: ON
SET ENGINE DISPLAY ON MFD

The investigator briefed the participant as follows:

1. You are departing KDAB on a VFR flight to KGNV. You are delivering organs from Halifax hospital, to the University of Florida for a liver transplant.
2. You have planned to go VFR at 4500 (see page 3) feet with flight following. The forecasted weather along the route is VFR. Your call sign is "Riddle Life Flight 321".
3. You are unable to program anything on neither the MFD nor the PFD but you can use the VOR navigation aides.
4. A sectional of Jacksonville will be provided to you in the simulator.

Departure time 1400z
KDAB 011353Z 29013KT 10SM SCT080 23/15 A29.92
KGNV 011353Z 21012KT 9SM SCT012 BKN070 23/21 A29.92

Initial Conditions:
Aircraft running on Runway 25 at KDAB
Weather set to match ATIS at KDAB

Daytona Beach ATIS information:
KDAB ATIS information Alpha
1353 Zulu Observation
Wind 290 at 13
Visibility 10
Ceiling 8000 scattered
Temperature 23, dew point 15
Altimeter 29.92
Landing and departing runways 25R and 25L
Contact clearance delivery on 119.3 prior to taxi
Advise on initial contact you have information Alpha

Riddle Life Flight 321, Daytona Beach Clearance. Maintain VFR at or below 3000
Departure Frequency 125.8, squawk 1234

Riddle Life Flight 321, runway 25R. Maintain runway heading. Cleared for takeoff.

Start timer to measure total flight time and time of weather *events.*

Passing 800 feet--- *Riddle Life Flight 321, turn right heading 290, contact departure.*

Riddle Life Flight 321, radar contact. Climb to requested altitude, resume own navigation to Gainesville.

10 minutes after takeoff

Riddle Life Flight 321, contact Jacksonville center on 125.30

Riddle Life Flight, roger radar contact. Maintain VFR proceed to Gainesville.

We are now simulating radio transmitter failure. When the participant makes radio calls to ATC the person acting like ATC will ignore these calls, but continue to make radio transmissions to other traffic.

Make random radio transmissions to other traffic throughout the rest of the flight.

Subject recognizes lost communications after minutes ________ MIN

Gradual degradation of weather:

1. 30 minutes after departure lower in-flight visibility to 5 miles in haze and ceiling to 5000 (5/8) broken cloud base
2. 31 minutes after departure change ceiling at from 5000 (5/8) broken cloud base to 5000 (6/8) broken cloud base.
3. 32 minutes after departure lower in-flight visibility to 3 miles and ceiling to 5000 (7/8) broken cloud base.

ATIS only receivable after passing Palatka (28J)

He should be about 25 miles or less from GNV when he calls for ATIS.
Once pilot dials in ATIS 127.15 you can make this reading.

KGNV ATIS
Information Bravo
1443 Zulu Special observation
Wind 290 at 13
Visibility 4BR, -SHRA SAY 4mile visibility and mist and for Shra SAY light rain and showers.
Ceiling 1500 Broken. 7000 Overcast
Temperature 23, dew point 23
Altimeter 29.87
Landing and departing runway 29
Advise on initial contact you have information Bravo.

Weather change when passing over Palatka:

1. Increase in-flight visibility to 5 miles
2. Change ceiling from 5000 (7/8) broken to 7000 overcast.
3. Set rain to moderate.

Weather change 10 miles from Gainesville:

1. Add clouds at 1500 scattered.
2. Lower visibility to 3 miles.

If the participant flew over Palatka before 30 minutes had passed the Palatka weather changes were not implemented. The participants received the weather changes 30 minutes into the flight and if continued to the destination received the weather changes 10 miles from Gainesville with rain set to moderate.

Continued:
The participant did not divert and landed at Gainesville __________ minutes after takeoff

Diverted:
The participant diverted __________ minutes after takeoff.