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Center for Advanced Multimodal Mobility

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INVESTIGATE AGE IMPACTS ON CONTROLLED FLIGHT INTO TERRAIN (CFIT) CRASHES IN GENERAL AVIATION

Final Report

by

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DISCLAIMER

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EXECUTIVE SUMMARY

Controlled Flight into Terrain (CFIT) crash is defined as an unintentional collision with terrain (the ground, a mountain, a body of water, or an obstacle) while an aircraft is under positive control. It is one of three high-risk accident occurrence categories identified by the International Civil Aviation Organization. Although advanced technologies have dramatically reduced the number of General Aviation CFIT crashes over the past 20 years, CFIT crashes continue to occur and at least half of them are fatal. Therefore, it is quite momentous to identify the contributing factors and recommend countermeasures to prevent or mitigate CFIT crashes. This research utilized the General Aviation CFIT crash data collected from the National Transportation Safety Board (NTSB) and pilots' information from the Federal Aviation Administration (FAA), to perform statistical analysis to reveal the impacts of pilots' age and other pilot-related contributing factors on the occurrence of CFIT crashes in General Aviation. Based on the analysis, policy-level recommendations were proposed to reduce or mitigate CFIT crashes. The research findings can help policymakers to better understand the underlying reasons for General Aviation CFIT crashes and update their current practices and regulations.

Chapter 1. Introduction

1.1 Problem Statement

Controlled Flight into Terrain (CFIT) is defined as an unintentional collision with terrain (the ground, a mountain, a body of water, or an obstacle) while an aircraft is under positive control. It is one of three high-risk accident occurrence categories identified by the International Civil Aviation Organization. Figure 1.1 shows that over the 10 years, all CFIT accidents that happened in 2012, 2013, 2015, 2017, 2018, and 2020 were fatal. Although advanced technologies have dramatically reduced the number of General Aviation CFIT crashes over the past 10 years, CFIT crashes continue to occur, and the survival rate for this category of crashes remains high.

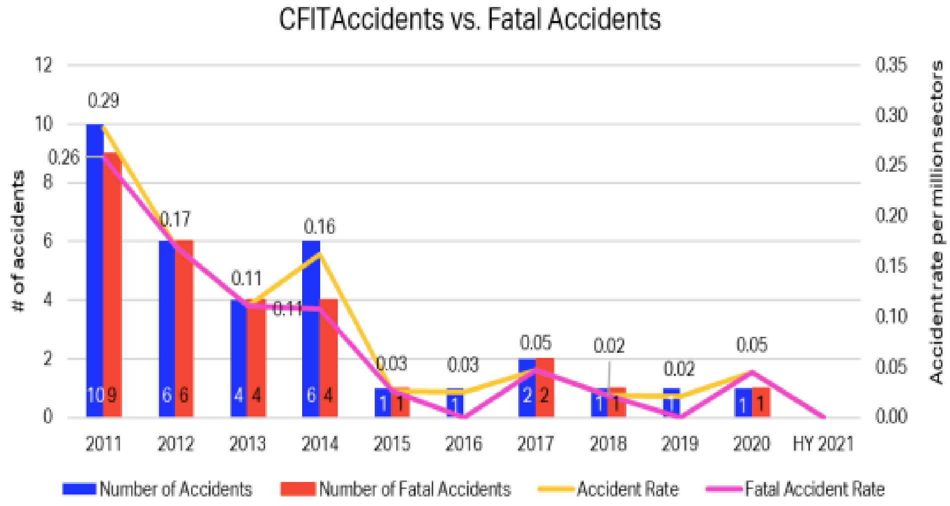


Figure 1.1. Controlled Flight into Terrain (CFIT) Accidents' Analysis (IATA, 2021, pg. 8)

Therefore, it is quite important to investigate the factors contributing to CFIT crashes and to propose countermeasures to prevent or mitigate CFIT crashes in General Aviation. Several research works have been conducted on CFIT crashes. Some of the research investigated the causes of CFIT crashes. For example, system-induced errors (Wiener,1977), human errors (Thomas, 2000; Kelly and Efthymiou, 2019), and executive mismanagement (Ladkin, 1997) have been identified as causes of CFIT crashes. Bazargan and Vitaly (2011) and Mortimer (1991)'s research found that for certain groups of accidents, pilots aged 60 and over were involved in more accidents when compared to others examined (Mortimer, 1991; Bazargan and Guzhva 2011). However, there is no research focused on the impacts of pilots' age on the occurrence of CFIT crashes in General Aviation. For Commercial Aviation, there is a mandatory retirement age for pilots which is 65 years old. However, there is no such age requirement for General Aviation. Therefore, more elderly pilots are flying in the General Aviation community, which may be the reason for the high number of CFIT crashes in General Aviation. To fill the gap and investigate the relationship between pilots' physical characteristics and CFIT crashes, this research will examine the recent three years (2016-2018) of General Aviation CFIT crashes to uncover the age, as well as other pilot-related factors contributing to CFIT crashes, such as gender, medical certificate, etc. In addition, based on the identified contributing factors, recommendations will be proposed to mitigate CFIT crashes in General Aviation.

The focus of this research is General Aviation (GA). General Aviation (GA) represents all civil aviation "aircraft operation other than a commercial air transport or an aerial work operation"(Annex, 2010). The United States has a very large and diverse General Aviation community. General Aviation covers a wide range of aerial operations such as law enforcement, medical transport, overnight delivery, survey and mapping, aerial firefighting, agricultural aviation, business and personal travel, sightseeing et al. Technology has increased in Commercial Aviation over the years; however, most GA aircraft are not technologically equipped with advanced alert systems, multi-crew operations, and required flight plans, leaving the pilot fully responsible for identifying pressing concerns while managing tasks in the aircraft during each flight. General Aviation (Part 91) is typically seen as one of the least restrictive parts of the regulations. This does not imply unsafe or out of standard; however, it implies that weather conditions, environmental condition restrictions, fuel reserves, and crew flight duty periods may not be required. Also, this may have less emphasis because of the type of flight operations. CFIT crashes in General Aviation have great economic and societal impacts. Improving the safety of General Aviation could not only save lives but also save economic and societal costs.

CFIT accidents occur across a range of pilot experiences. These pilot experiences include huge pilot error factors as well as age impacts, gender, medical certificates, single pilot resource management, etc. CFIT accidents are liable to occur if the pilot at any phase of the flight loses Situational Awareness, is distracted, and complacency as outlined previously. This research study plans to determine whether General Aviation has a high emphasis on individual pilot responsibility. Therefore, investigating pilot-related factors contributing to CFIT crashes reveals whether the accidents have a high chance of pilot error. CFIT accidents can be prevented with proper precautions. It can be noted that the largest component is Situational Awareness which is an individual responsibility. The FAA pinpoints individual pilot issues as human factors if present. The interference with safe flight may cause human factors due to undesirable mishaps in the aircraft. Objectives

This project is to investigate the impacts of pilots' age and other pilot-related factors contributing to CFIT crashes in General Aviation and to recommend countermeasures to prevent or mitigate CFIT crashes. Specific project objectives include:

1) Review current practices and regulations on safety operations in General Aviation
2) Identify pilot-related factors contributing to CFIT crashes in General Aviation
3) Investigate the impacts of pilots' age on the occurrence of CFIT crashes in General Aviation
4) Recommend countermeasures to mitigate General Aviation CFIT crashes.

1.2 Expected Contributions

This research will benefit the General Aviation pilot population by outlining notable safety deficiencies to ultimately decrease safety crashes as well as high fatality outcomes. Pilot-related factors have contributed to many accidents, incidents, and safety margins which continue to be recalculated as countermeasures to be implemented. The results of the research will provide an in-depth understanding of the occurrence of CFIT crashes, and help policymakers to update current practices and regulations to reduce CFIT crashes in General Aviation.

1.3 Report Overview

The remainder of this report is organized to address this research study and future research as follows: Chapter 1: Introduction which includes background, and research objectives for the study. Chapter 2: Literature Review which discusses previous research on CFIT crashes, safety accidents impact, human factors in aviation, safety models, as well as safety recommendations. Chapter 3: Data Description which includes the data used for this study, and how they were collected and processed. Chapter 4: Data Analysis Results which includes descriptive analysis, comparison analysis, and summarized findings. Lastly, Chapter 5: Conclusion and Recommendations for future research.

Chapter 2. Literature Review

2.1 Introduction

Firstly, this chapter addresses the impacts of safety accidents which are outlined in the literature review which details the importance of finding a solution to mitigate aviation safety accidents. Next, it will cover pilot-related factors that contribute to safety crashes. Another item discussed is human factors outside of aviation which may affect the pilot’s ability to perform in an aircraft under any circumstances. Fourthly, how crashes are investigated, and the process the NTSB and FAA take to thoroughly find the cause of safety crashes are presented. The fifth part of this research includes aviation safety models and the result of investigative recommendations. Sixth, existing recommendations for safe flight operations are summarized. Lastly, a summary of the studies is discussed.

2.2 Impacts of Safety Accidents on Aviation

A research study (Price & Groff, 2002) discovered the overall case fatality rate for the sample was 62.4%. Case fatality rates for all levels of each independent variable are shown in Table 2.1. Case fatality rate increases as pilots’ age increases.

Table 2.1. Fatalities Based on Age

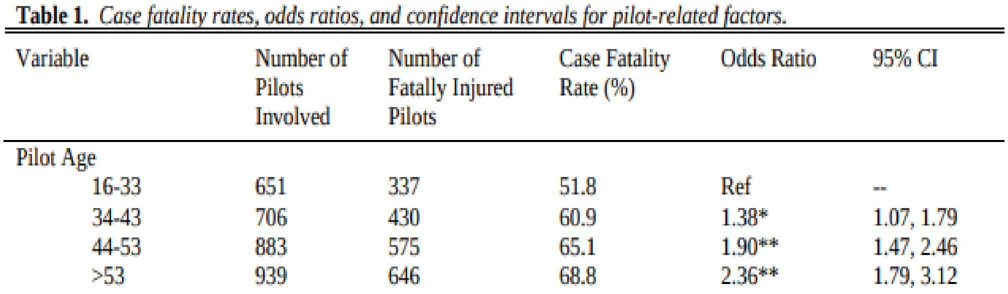


Table 1. *Case fatality rates, odds ratios, and confidence intervals for pilot-related factors.*

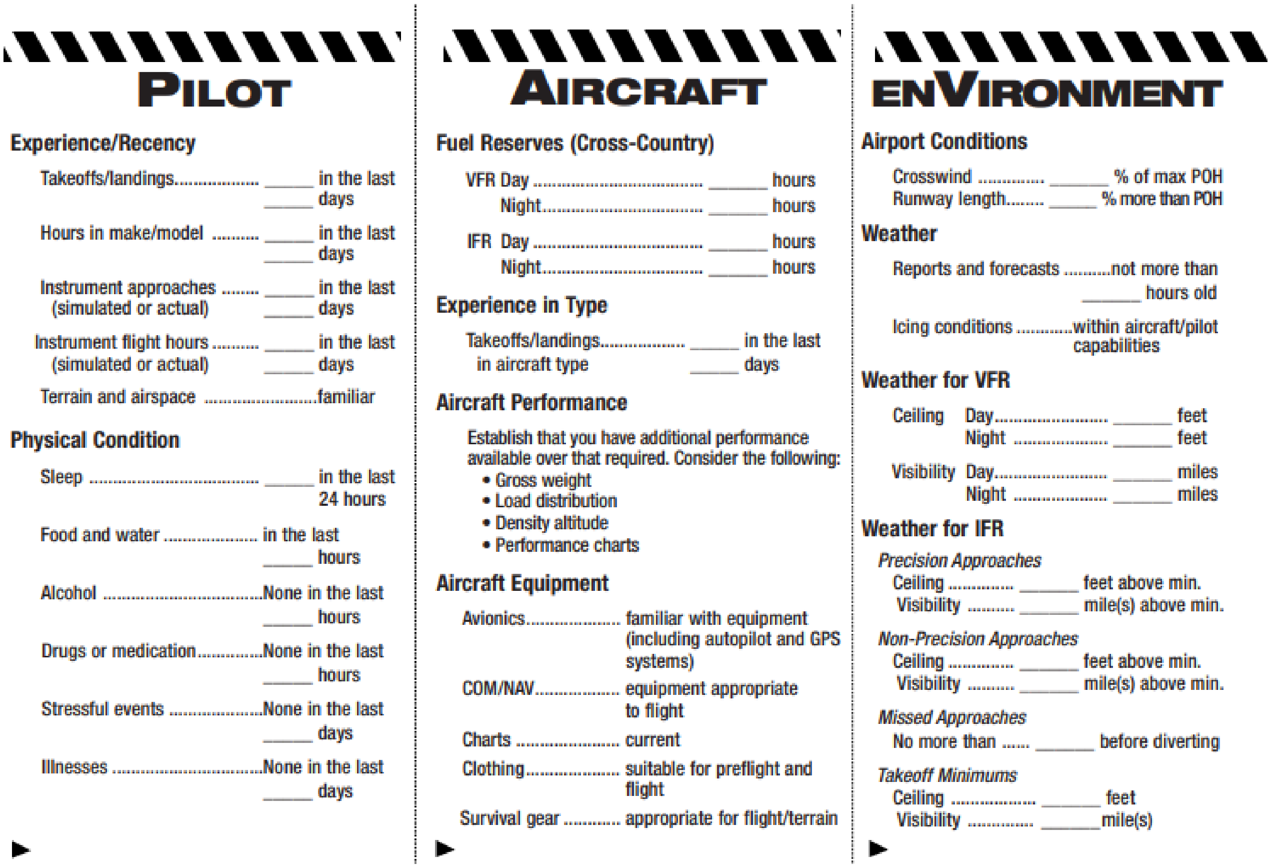
Variable	Number of Pilots Involved	Number of Fatally Injured Pilots	Case Fatality Rate (%)	Odds Ratio	95% CI
Pilot Age					
16-33	651	337	51.8	Ref	--
34-43	706	430	60.9	1.38*	1.07, 1.79
44-53	883	575	65.1	1.90**	1.47, 2.46
>53	939	646	68.8	2.36**	1.79, 3.12

Although General Aviation is safe there are many other ways to improve safety that are provided by utilizing systematic processes. Further research on General Aviation resulted in a few key statistical points. Whereby, the existing recommendations determined that there are more risks associated with Single Pilot Resource Management.

Flight planning requires an in-depth focus on gathering all relevant information for a safe flight which includes Pilot in Command (PIC) and Single Pilot (SP). In general Aviation, the PIC has the sole responsibility of gathering this information. On the other hand, SP operations are very safe; however, during the flight, if anything arises it is the responsibility of SP to overcome and fly the plane safely. Examples of situations that may arise include last-minute changes to flight, diversions, weather, physical challenges (headaches, dizziness, airsickness), or extremely high workload.

Risk Management is used in the Aviation environment to define a safe process for pilots to follow which includes Pave checklist (PC), Risk Management Checklist (RMC), Pilot’s Risk Management Checklist (PRMC), Pre-Flight Checklists (PFC) and Risk Management Checklist

(RMC). The PC is best known as a PRMC shown in Figure 2.1, which encourages the pilot to assess the Pilot, Aircraft Environment, and External Pressures. These checklists referenced are classified as PFC prior to getting into the plane to fly. RMC is used to mitigate risk during flight and is identified prior to takeoff in the preflight planning phases.



PILOT

Experience/Recency

Takeoffs/landings.................. ______ in the last ______ days

Hours in make/model .... ______ in the last ______ days

Instrument approaches .... (simulated or actual) ______ in the last ______ days

Instrument flight hours .... (simulated or actual) ______ in the last ______ days

Terrain and airspace ....familiar

Physical Condition

Sleep .... ______ in the last 24 hours

Food and water .... in the last ______ hours

Alcohol ....None in the last ______ hours

Drugs or medication..............None in the last ______ hours

Stressful events ....None in the last ______ days

Illnesses ....None in the last ______ days

▶

AIRCRAFT

Fuel Reserves (Cross-Country)

VFR Day .... ______ hours

Night.................................. ______ hours

IFR Day .... ______ hours

Night.................................. ______ hours

Experience in Type

Takeoffs/landings.................. ______ in the last
in aircraft type ______ days

Aircraft Performance

Establish that you have additional performance available over that required. Consider the following:

- Gross weight
- Load distribution
- Density altitude
- Performance charts

Aircraft Equipment

Avionics.................... familiar with equipment (including autopilot and GPS systems)

COM/NAV................. equipment appropriate to flight

Charts .... current

Clothing.................... suitable for preflight and flight

Survival gear .... appropriate for flight/terrain

▶

ENVIRONMENT

Airport Conditions

Crosswind .... ______ % of max POH

Runway length........ ______ % more than POH

Weather

Reports and forecasts ....not more than ______ hours old

Icing conditions ....within aircraft/pilot capabilities

Weather for VFR

Ceiling Day....................... ______ feet
Night .... ______ feet

Visibility Day....................... ______ miles
Night .... ______ miles

Weather for IFR

Precision Approaches
Ceiling .... ______ feet above min.
Visibility .... ______ mile(s) above min.

Non-Precision Approaches
Ceiling .... ______ feet above min.
Visibility .... ______ mile(s) above min.

Missed Approaches
No more than ...... ______ before diverting

Takeoff Minimums
Ceiling .... ______ feet
Visibility .... ______ mile(s)

▶

Figure 2.1: Industry Training Standards (FAA, FITS)

During this process, pilot's practice Go/No-Go decision making. The thorough assessment of the Aircraft include required documentation for aircraft/pilot, required inspections on aircraft completed, weather for duration of flight, and Personal Minimums Checklist (PMC) are the first steps to the verification checks for pilots. In General Aviation pilots can use the NWKRAFT checklist for cross-country (XC) planning with the intent to gather a clear plan and expectation of a planned flight.

LEGEND:

N- Notams (Notice to Air Missions) A NOTAM is a notice containing information essential to personnel concerned with flight operations but not known far enough in advance to be publicized by other means
W- Weather
K-Known ATC Delays
R-Runway Lengths
A- Alternate Airport in case the flight cannot be completed as expected

F- Fuel Requirements
T- Takeoff and Landing

Flight Planning is one of the largest safety components of flying and will always be the core of taking a flight. A list of components required for Flight Planning includes aviation, flight training, implementing safety measures, and logbook information entry. Aviation is designed to gather all information before departing and have available contingency plans in case anything unexpected arises. Flight training is extensive and foundationally prepares the pilot, where these skills are taught. As a pilot continues in aviation, it remains a training environment due to currency, proficiency, flight reviews, and recurrent training. Pilots demonstrate safety during the checkpoints and typically receive a signoff from a Flight Instructor, or Designated Pilot Examiner. Pilots are required to maintain their Logbook where all flights, training, currencies, and endorsements, are kept for pilot experience recordkeeping.

2.3 Pilot-Related Factors Causing Aviation Accidents

Upon research, factors were used to find the root cause analysis of aviation accidents including the pilot's information, training records, training habits, medical holding for fitness of flight, single pilot resource management versus crew resource management, currency in the aircraft, proficiency in given flight operations and type of flight (occupational, recreational, training). There are six key contributing factors related to safety occurrences that were significant to this research based on the FAA Accident Cause Factors: (FAA, AIM Section 6. Potential Flight Hazards 2022 Ch 7-6-1) which are as follows:

1. **Faulty Decision Making/ Poor Decision Making.** Pilots make all decisions regarding continuing flight into questionable weather conditions, known malfunctions, or ineffective planning that exceeds the pilot's capabilities.
2. **Low Altitudes in Unfamiliar Areas.** Pilots maneuvering at low altitudes in unfamiliar areas increase the risk of unintentional collisions with elevated terrain, such as buildings, towers, mountainous terrain, power lines, and construction machinery.
3. **Improper Procedures in Instrument Meteorological Conditions (IMC).** IMC is a heavily trained area for pilots which must maintain basic currency due to the complicated procedures. Pilots are required to remain up to date on these procedures to reduce over-task saturation and lack of situational awareness when flying with flight instruments in reduced visibility or clouds.
4. **Training.** Although, pilots become licensed their mindset is required to remain in training mode for their entire career due to changes in safety recommendations, high-intensity workload, and emergency procedures. Faulty decision-making and lack of situational awareness over time may be identified in the training environment by Certified Flight Instructors.
5. **Lack of Aeronautical Decision Making.** Pilots must identify the risk during flight being aware of and quick to respond to elevated risk situations prior to the development of imminent danger. Once a risk is identified, pilots should execute

all available options and resources such as a diversion to another airport or safer conditions.

6. **Lack of Preflight Planning.** During a proper pre-flight, the pilot gathers all relevant information for the flight such as plans for an alternate airport (diversion) and a plan of action. Planning eliminates the risk that comes with elevated task saturation. This is because the pilot is responsible for flying the plane. Additionally, planning needs to be detailed to avoid distractions leading to loss of situational awareness and ultimately creating an irreversible dangerous situation, especially in Single Pilot Resource Management (SPRM).

Task saturation in the aircraft is naturally elevated during critical phases of flight takeoff, and landing. Each flight has a safety margin and procedures to identify hazards to respond efficiently. During either the takeoff phase, aborted takeoff, or immediate landing, the pilots are trained with these emergency response options in mind. During the landing phases, there are go-around procedures in place for unsafe landing or unstable approaches, and diversions to another airport if the pilot’s capabilities are exceeded at that airport (winds, runway length, traffic, experience) shown in Figure 2.2.

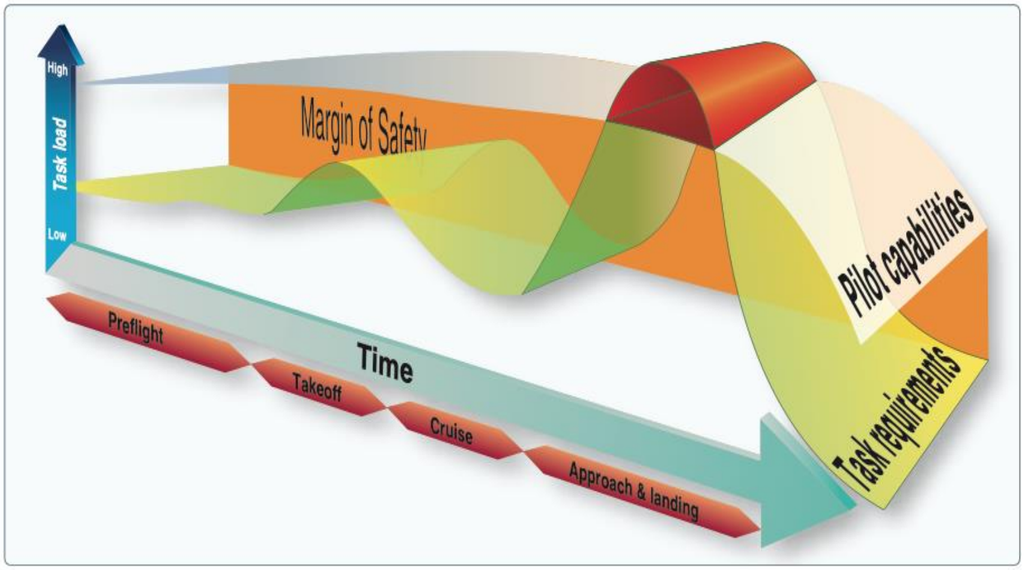


Figure 2.2. Pilot's Handbook of Aeronautical Knowledge (FAA, 2016 Pg. 2-25)

Single Resource Management (SRM) is more common; however, may become saturated very quickly in any adverse situations. Contributing factors to CFIT accidents may result in the pilot becoming overly task-saturated in environments that have reduced visibility weather causing the loss of situational awareness while flying.

The misconception of the pilot not having the aircraft under positive control is not when the plane is completely out of control. This occurs when the pilot loses awareness of where the aircraft’s position is located based on their cognition. Being disorientated in reduced visibility due to flying the aircraft based on the instrumentation's improper settings. The aircraft may unintentionally be in a nose-down attitude resulting in the aircraft gaining speed while descending at a rapid rate of more than 1,000ft per minute. This situation may ultimately cause issues with the pilot recovering the airplane in enough time.

The aim of the research is to determine the possibility that CFIT accidents are caused due to confusion or reduced visibility while the pilot is flying in cloudy. Pilots have specific altitudes set to fly for obstacle clearances; however, in high-elevation areas like Denver, there is a possibility that this is a high risk for pilots who lose their situational awareness. Pilots being unfamiliar with the area stand a chance of being just as detrimental as a pilot being too familiar and relaxed in the area. While receiving clearances and proper altitudes based on changes of demographic areas it is imperative for the pilot to remain vigilant of the surrounding areas.

Flight performance and cognitive proficiency differences were reviewed in studies that were related to perceptual-motor skills, fast reaction times, and moving forward/backward and sideways simultaneously. Additionally, for example, Spatial Awareness is performing multiple cognitive functions at once, circular motion over the stomach and tapping the top of the head simultaneously for example. Flying requires considerable physical, and perceptual-motor skills and high-level cognitive functionality.

In General Aviation (GA), the Aeronautical Decision Making (ADM) is a huge safety factor that explains how pilots respond to situations in the plane. It is the foundation that is solely based on the pilots and the flight training environment, tough decisions could heavily weigh down on the pilots as multiple tasks can overwhelm any pilot regardless of age or experience. Investigating Age impacts and relating to cognitive measurement are associated directly with a pilot’s skills and abilities is not definitive; however, the purpose of this research is to identify additional measures to keep all pilots safe.

As previously stated, flying a plane is inherently risky and could result in errors if not properly mitigated during each flight. A pilot’s perception of flying is attributed to the type of planning done for each flight. According to many studies including the NTSB, upwards of 80% of accidents are caused by pilot error. General Aviation has statistically higher accidents and fatalities which increases the pilots' risk perception and reaction to unsafe conditions in the plane. Studies have shown that “Gender, age, marital status, race/ethnicity, education level, flight hours, single-multi-engine hours, hours as PIC, type of flight training, number of FAA licenses/ratings, number of hazardous events pilots were involved in, self-efficacy, aviation safety attitudes, level of psychological distress, and focus of control.” (Nuhu, 2019)

These variables contribute to job performance and it is determined that aviation is an extremely high-demand activity. A Pilot’s risk perception may cause a pilot to continue flying in adverse conditions. Although General Aviation flight operations are typically not for hire unless operations involve flight instruction, pilots still have reasons to fly, which is a personal motivation or an external pressure that is not limited to meetings, travel for work, family, events, and maintenance that entice the pilot to continue in adverse conditions ultimately resulting in a safety incident. Woods identified that Aeronautical decision-making can be affected by personal-based desires. “The National Transportation Safety Board (NTSB) has determined that continued flight into inclement weather is a major safety hazard within GA, and more than 70 percent of the accidents that occurred in IMC were fatal compared to 15 percent of those that occurred within visual meteorological conditions” (Woods, 2020). CFIT accidents statistically happen if a pilot unintentionally collides with terrain, especially in the transition from Visually Meteorological Conditions (VMC) to IMC.

Medical examinations for pilots are required and determine the overall fitness of flying for a pilot. This is dependent on three types of medical holding 1st Class, 2nd Class, and 3rd Class taking into consideration age, human bodies naturally go through a transition of deteriorating health conditions whether it is minor changes. Flying is extremely task-saturated which may create impairments dependent on the pilot being under stressors at any age or level of experience. However, age is not a restriction, nor does it deprive a pilot from flying. In certain situations, preventative measures were put in place to assist.

2.4 Human Factors in Aviation Safety

Human factors could lead to human error accidents. Human error is defined as an error action by a professional resulting in an unintentional consequence. The FAA and other safety organizations considered human factors in pilots, air traffic controllers, and aircraft mechanics and uncovered causes of accidents that could have been mitigated. There are multiple safety models to identify human factors focusing on the psychology and biology of the professional. This assists in ensuring their individual ability to overcome these situations while performing an already stressful and task-saturated job.

Safety accidents may be attributed to human error for multiple reasons which is often due to the relationship between the professional’s personal life, organization, and duties of the career may lead to some unfortunate mishaps. Figure 2.3 shows different concepts related to science, current practices per the organization, and human factors. The Human Factor Analysis and Classification System (HFACS) developed by Dr. Scott Shapell and Dr Doug Wiegmann (The HFACS framework, 2014) is heavily based on Reason’s Swiss Cheese model and is a tool to assist the investigative process on safety accidents. Under preconditions for unsafe acts, human factors were identified as a contributing factor. “Aviation accidents are typically the result of a chain of events that often culminate with the unsafe acts of operators (aircrew)” (Shappell et al., 2006).

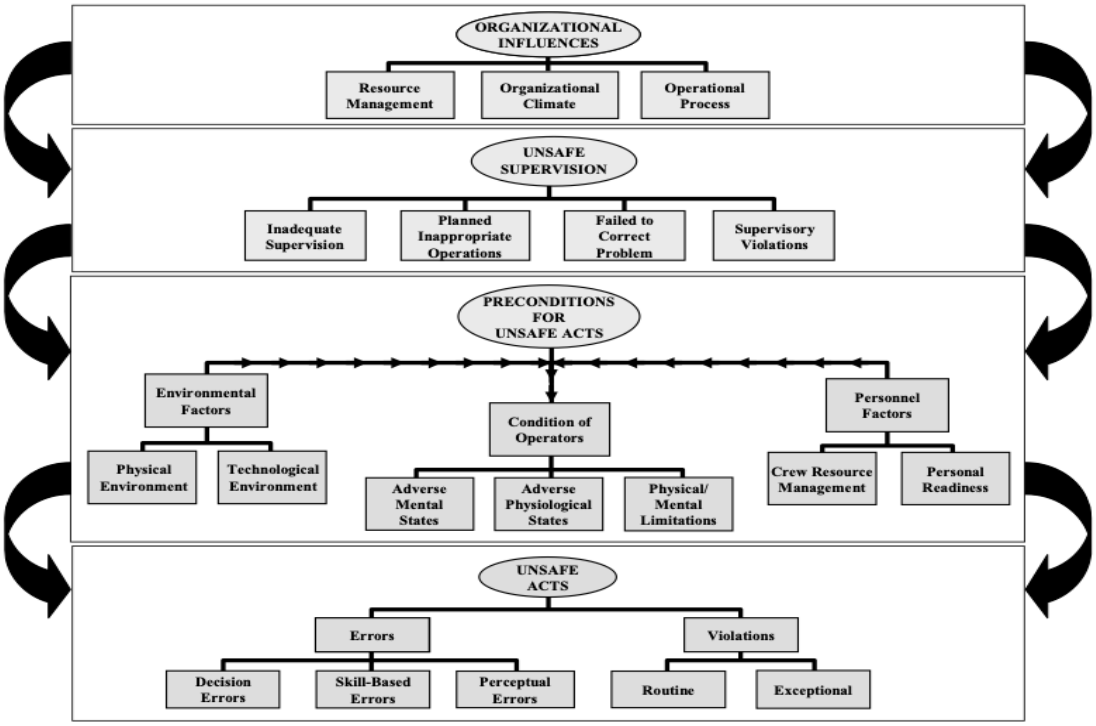


Figure 2.3. Human Error Model (Shapell and Wiegmann, 2014)

Hazardous Attitudes and Antidotes have been researched for many years in aviation. A pilot’s attitude affects the quality of decisions made in the aircraft. Furthermore, hazardous attitudes may lead to poor judgment such as continuing a flight in deteriorating conditions. Pilots’ antidotes for hazardous attitudes are taught during training; however, it is up to the pilot to reassess ensuring that it neutralizes such attitudes. The FAA suggests the antidotes should be memorized by each pilot and allow mitigation for the current situation. Figure 2.4 outlines the hazardous attitudes, which are the pilot’s individual responsibility to check and mitigate so there is no interference when making safety decisions. Flying is like any other skill, once a pilot is experienced it is required to maintain an understanding that each flight is inherently risky; however, following the standard safety models will ensure that risk is mitigated effectively and efficiently.

The Five Hazardous Attitudes	Antidote
Anti-authority: "Don't tell me." This attitude is found in people who do not like anyone telling them what to do. In a sense, they are saying, "No one can tell me what to do." They may be resentful of having someone tell them what to do or may regard rules, regulations, and procedures as silly or unnecessary. However, it is always your prerogative to question authority if you feel it is in error.	**Follow the rules. They are usually right.**
Impulsivity: "Do it quickly." This is the attitude of people who frequently feel the need to do something, anything, immediately. They do not stop to think about what they are about to do, they do not select the best alternative, and they do the first thing that comes to mind.	**Not so fast. Think first.**
Invulnerability: "It won't happen to me." Many people falsely believe that accidents happen to others, but never to them. They know accidents can happen, and they know that anyone can be affected. However, they never really feel or believe that they will be personally involved. Pilots who think this way are more likely to take chances and increase risk.	**It could happen to me.**
Macho: "I can do it." Pilots who are always trying to prove that they are better than anyone else think, "I can do it—I'll show them." Pilots with this type of attitude will try to prove themselves by taking risks in order to impress others. While this pattern is thought to be a male characteristic, women are equally susceptible.	**Taking chances is foolish.**
Resignation: "What's the use?" Pilots who think, "What's the use?" do not see themselves as being able to make a great deal of difference in what happens to them. When things go well, the pilot is apt to think that it is good luck. When things go badly, the pilot may feel that someone is out to get them or attribute it to bad luck. The pilot will leave the action to others, for better or worse. Sometimes, such pilots will even go along with unreasonable requests just to be a "nice guy."	**I'm not helpless. I can make a difference.**

Figure 2.4. Pilot's Handbook of Aeronautical Knowledge (FAA, 2016)

2.5 Accident Investigation Process

Aviation safety accidents are investigated to determine the root causes of the occurrence and ultimately make safety recommendations to prevent further accidents. Aviation Safety is the responsibility of all parties involved.

The US Department of Transportation (U.S DOT) is the Federal agency responsible for all modes of transportation. The Federal Aviation Administration (FAA) is the regulating agency for ensuring all regulative policies and procedures are met. Every component of aviation is regulated under the Federal Aviation Regulations (FARs) and Aeronautical Information Manual (AIM). The FARAIM is a yearly publication that provides regulations from a legal aspect. The National Transportation Safety Board (NTSB) investigates all modes of transportation to make recommendations that can be adapted to the regulations by the FAA, or recommendations for modes of transportation for safety considerations. (NTSB, 2023)

Investigative processes for aviation accidents consist of gathering, analyzing information, and determining the cause. The FAA identifies further why accidents happen and whether the regulations were reviewed in accordance during the incident. Safety Management Strategies has a 3-category process on safety occurrences which are dependent on reactive, proactive, and predictive situations. Reactive which only responds to incidents/accidents only after they have occurred. Organizations such as Airlines, Flight schools, Air Traffic Control Facilities, Aviation Mechanics, and Airport Managers should always follow the regulations, and recommendations which will result in being Proactive, which actively identifies hazards in the presence of the organization's processes. Predictive is the best margin to be in for safety, focusing on future occurrences, preventing them from happening, and saving lives.

The investigation process is initiated by the report of an accident, the investigative team is composed of highly skilled professionals with expertise related to accidents and incidents. To determine the root cause analysis, firstly, the investigative team defines the problem based on the current regulations, recommendations, policies, and procedures. The second step in the investigative process is data collection. To understand the implications or circumstances of the accident and incident, the pertinent information required includes the pilot's qualifications, medical certifications as well as pilot history, Aircraft's Airworthiness, maintenance history, performance measures, and limitations as outlined by the Aircraft make and model Pilot Operating Handbook, Airport category, and runway configuration, noting any information that could have contributed to the accident,

Air Traffic Controller and facility with the audio to recount the events leading up to the accident, time of day, current weather conditions, and how the weather affected the fight against the pilot's capabilities. Terrain and demographic layout information will be collected during this phase as well. The third process is event reconstruction, which involves assessing the accurate sequence of events leading to safety accidents and incidents.

The fourth stage is analyzing information and identifying the risk with explanations of technical operational factors and how the organization contributes. The NTSB investigative process typically uncovers the safety occurrence that happens due to a series of unsafe acts and neglect of procedures that ultimately lead to a mishap. Based on the research study two models that are utilized in this investigative process include causation and aviation safety model. Causation models are used in accident investigations to magnify those smaller issues that contribute to safety mishaps. Aviation Safety Models are heavily used in Aviation to successfully mitigate errors from previous accidents.

2.6 Aviation Safety Models

Safety Models are at the core of risk management. Over the years, the FAA has continuously worked on reducing risk in general aviation using statistics and safety models as a tool. There are stated outlining factors that contribute to these accidents including organizational factors, unsafe supervision, preconditions to unsafe acts, and ultimately the unsafe act. One of the largest safety models used in aviation is the Reason 1990 Swiss Cheese model which outlines the sections above. In Figure 2.5, the Swiss Cheese model is widely used in safety investigations, which concludes that accident occurrence is dependent on an identified issue. Using safety models during investigations allows preventative measures to be implemented for further policies. The NTSB's thorough investigative process is in place to uncover a plethora of inconsistencies leading up to the accident or incident.

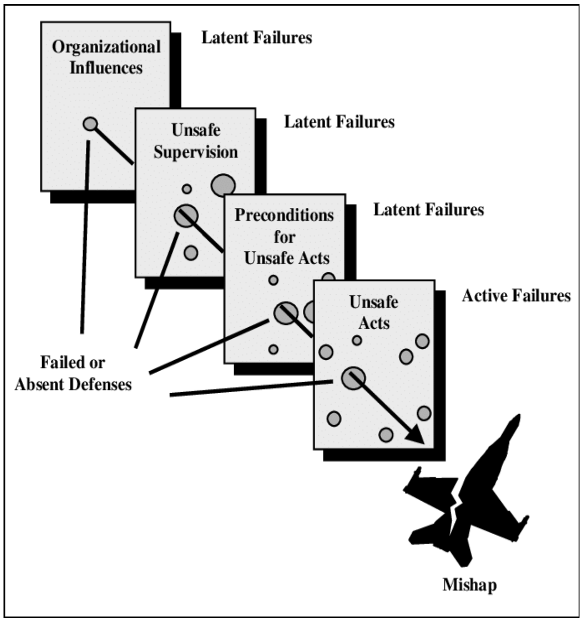
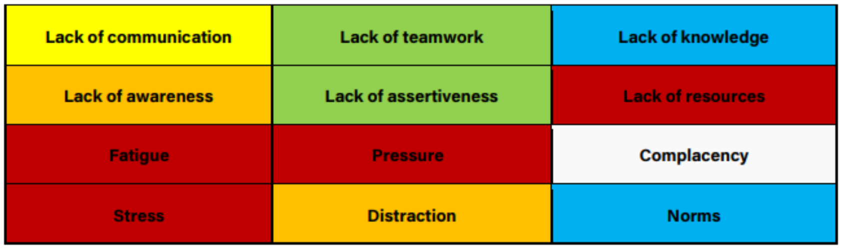


Figure 2.5. The "Swiss Cheese" model of human error causation adapted from reason (Reason 1990)

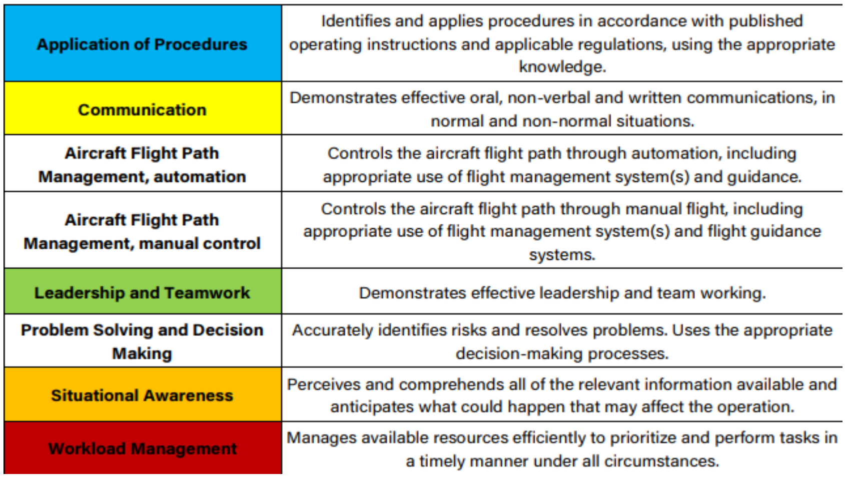
Dupont Human Performance Model 1993 and Pilot Competency Model are outlined below shown in Figure 2.6. To determine preventative measures, it is necessary careful investigation of the human errors resulting in safety occurrences in the aircraft the origin of the accident or incident must be identified and mitigated. Another model is the Pilot Competency Model which identifies the issues of individual pilot's performance and human error association. Figure 2.6 below is color-coded for Human Factor and Pilot Competency overlap and the effects on the safety outcome of flight.

The most important key points of the model are major human factors, fatigue, stress, pressure, and lack of resources, a pilot's performing capabilities are foundational in his/her personal life, and external pressures result in reduced performance which is dependent on the workload increase. Furthermore, this research confirmed how important safety models are in identifying existing factors contributing to safety accidents.



Lack of communication	Lack of teamwork	Lack of knowledge
Lack of awareness	Lack of assertiveness	Lack of resources
Fatigue	Pressure	Complacency
Stress	Distraction	Norms

a) Dupont Human Factor Model



Application of Procedures	Identifies and applies procedures in accordance with published operating instructions and applicable regulations, using the appropriate knowledge.
Communication	Demonstrates effective oral, non-verbal and written communications, in normal and non-normal situations.
Aircraft Flight Path Management, automation	Controls the aircraft flight path through automation, including appropriate use of flight management system(s) and guidance.
Aircraft Flight Path Management, manual control	Controls the aircraft flight path through manual flight, including appropriate use of flight management system(s) and flight guidance systems.
Leadership and Teamwork	Demonstrates effective leadership and team working.
Problem Solving and Decision Making	Accurately identifies risks and resolves problems. Uses the appropriate decision-making processes.
Situational Awareness	Perceives and comprehends all of the relevant information available and anticipates what could happen that may affect the operation.
Workload Management	Manages available resources efficiently to prioritize and perform tasks in a timely manner under all circumstances.

b) ICAO Pilot Competencies Model

Figure 2.6. Dupont Human Factor Model and ICAO Pilot Competencies Model (IATA, 2016)

Situational Awareness per the FAA is defined as “The accurate perception and understanding of all the factors and conditions within the four fundamental risk elements that affect safety before, during, and after the flight.” To maintain situational awareness, a pilot needs to understand the relative significance of these factors and their future impact on the flight. When a pilot is situationally aware, he or she has an overview of the total operation. Situational Awareness is a constant assessment of safety, and any loss of SA will result in negative impacts on the flight. The FAA has outlined why Situational Awareness is extremely important and how it affects increased chances of accidents/incidents such as CFIT.

> “*Some obstacles to maintaining situational awareness include (but are not limited to) fatigue, stress, and work overload; complacency; and classic behavioral traps such as the drive to meet or exceed flight goals. Situational awareness depends on the ability to switch rapidly between several different, and possibly competing, information sources and tasks while maintaining a collective view of the environment. Experienced pilots are better able to interpret a situation because of their base of experience, but newer pilots can compensate for lack of experience with the appropriate fundamental core competencies acquired during initial and recurrent flight training. SRM training helps*

> *the pilot maintain situational awareness, which enables the pilot to assess and manage risk and make accurate and timely decisions. To maintain situational awareness, all the skills involved in ADM are used" (FAA, Aviation Handbooks & Manuals 2001 pg. 1-10)*

Low-time students/pilots are not always associated with inexperience because training environments are usually strict and heavily regulated due to the safety of training new pilots. New pilots are trained to fly, and graded on performance, which keeps them current and proficient. Ground school lessons, Flight Training Devices, and Airplane Flight Training are used most to ensure proper reaction to flight safety scenarios. Often retired pilots revert to General Aviation typically in a more leisure capacity after a long career of flying professionally. CFIT accidents remain a looming reality of flying, factors do arise including the pilot's abilities to overcome high stress, maintain situational awareness, maintain currency, and proficiency.

Flight performance and cognitive proficiency differences were in studies related to perceptual- motor skills, fast reaction times, and moving forward/backward and side-ways simultaneously (Groucho, 2022). Spatial awareness performs multiple cognitive functions at once, circular motion over the stomach and tapping the top of the head simultaneously. Flying requires considerable physical, and perceptual-motor skills and high-level cognitive functionality. In General Aviation, Aeronautical Decision Making is solely based on the pilots and or flight training environment. Pilots become overwhelmed due to task saturation regardless of age or experience. Investigating age impacts and relating to cognitive measurement associated directly with a pilot's skills and abilities is not straightforward or definitive.

Threat Error Management (TEM) is a safety model used originally in Commercial Aviation but later adapted to General Aviation for better training and safety considerations while flying. TEM is divided into three categories: (ICAO, 2018). Figure 2.7 is the TEM Model in flight operations.

> Threat: Threats are defined as "events or errors that occur beyond the influence of the flight crew, increase operational complexity, and which must be managed to maintain the margins of safety" which can consist of different types of threats (anticipated, unexpected, or latent).
>
> Error: "actions or inactions by the flight crew that leads to deviations from organizational or flight crew intentions or expectations". The flight crew did not revert to training and or proper procedures in reaction to the treat resulting pin error.
>
> Undesired Aircraft State (UAS): "flight crew-induced aircraft position or speed deviations, misapplication of flight controls, or incorrect systems configuration, associated with a reduction in margins of safety".

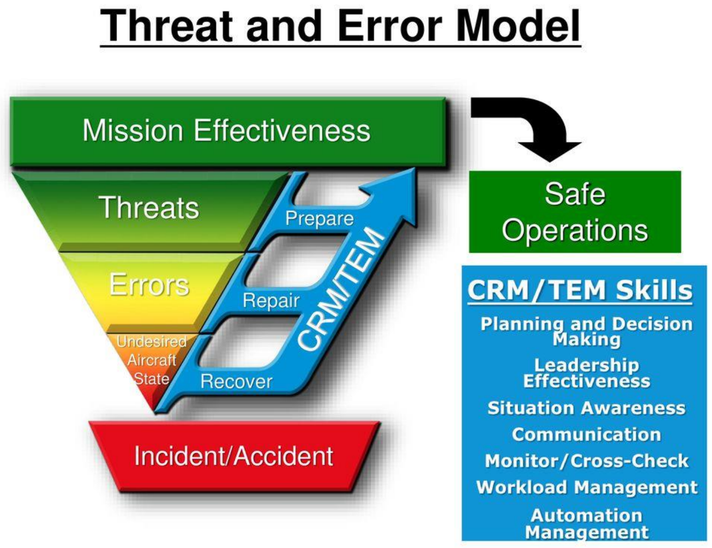


Figure 2.7. Threat and Error Model (ICAO, 2018)

More adaptation of TEM in General Aviation and training environments increases safety operations and better skills. Although the model is based on CRM, and the majority of the General Aviation flight operations are conducted under SRM, emphasis on training in situational awareness, planning and decision making, workload management, and automation management can increase the already existing model of “Aviate, Navigate, Communicate” (FAA, Fly the aircraft first - federal aviation administration). This safety aviation model helps pilots remember the importance of flying the aircraft and maintain positive control, then regain situational awareness in the flight path, and lastly communicate with air traffic control or respond to radio calls.

2.7 Summary

Aviation safety is a high priority and requires seamless investigative processes resulting in proper safety recommendations. In General Aviation, the person-to-aircraft ratio is significantly smaller than larger airplanes. A typical General Aviation aircraft holds less than nine passengers, based on this research study, only eight percent (8%) of the accidents had passengers on board totaling less than ten people. General Aviation has significant safety procedures and research contributing to safety protocols; however, a lot of procedures are geared towards Commercial Aviation and human life ratio.

Chapter 3. Data Description

3.1 Introduction

For this project, the following data sets were used to conduct the analysis:

1. General aviation CFIT accident data and reports (2016-2018): National Transportation Safety Board (NTSB), https://www.ntsb.gov/Pages/AviationQuery.aspx

   The reports identify pilots' experience data, such as licenses, level of experience, age, gender, single pilot operations, dual pilot, types of aircraft flown, and medical certificate. Pilot data in the NTSB reports are very detailed and include historical data on accidents/incidents. The report also includes how the pilot gathered information for the flight via filed flight plans, or air traffic control communication. The crash incident data includes weather conditions, geographical locations, airport operations, runway conditions, aircraft make and model, aircraft maintenance history, owner's history, airworthiness directives, and engine maintenance history.

2. U.S. Civil Airmen Statistics: Federal Aviation Administration, (https://www.faa.gov/data_research/aviation_data_statistics/civil_airmen_statistics)

   All registered pilots' information can be collected from "The U.S. Civil Airmen Statistics", which is an annual study published to meet the demands of the Federal Aviation Administration (FAA), other government agencies, and the industry. It contains detailed airmen statistics not published in other FAA reports.

3.2 CFIT Accident Data

In total, there were 96 CFIT accidents occurred in General Aviation from 2016-2018. Since the accident data contains limited information about the pilots involved in these accidents, the research team reviewed all available accident investigation reports and extracted more information about the pilots, such as age, gender, etc. The following table shows the variables and their explanations for CFIT accident data.

Table 3.1 Variables and Explanations of CFIT Accident Data

Variable	Explanation
ntsb_no	Unique case number assigned to the accident by NTSB
Inj_tot_f	The total number of fatalities that resulted from an event
Inj_tot_s	The total number of serious injuries that resulted from an event
Ev_highest_injury	Indicate the highest level of injury among all injuries
CICTTphase	The phase of flight associated with the defining event of the accident aircraft
age	The age of the pilot
gender	The gender of the pilot
license/rate	The license category of the pilot
medical	The medical certificate issued to the pilot
occupational	Whether the pilot was an occupational pilot
second Pilot	Whether there was a second pilot

3.3 Pilot Information

U.S. Civil Airmen Statistics is an annual report that contains detailed airmen statistics, such as age, gender, medical certificate, license category, etc. Since the accident data collected were from 2016 to 2018; therefore, for comparison purposes, 2016-2018 Civil Airmen Statistics were used.

The pilot's information helps identify whether the accident was caused by any contributing factor of the pilot. The NTSB thorough investigation is complete once the events are recreated to demonstrate the cause of the mishap. All information is pertinent for investigation; however, this research is focused on contributing factors that are related to the pilot. These pilot-related factors included age, medical certificate, single-pilot management, crew resource management, and licenses held.

3.3.1 Certificate

The FAA outlines training for Flight Instructors to follow to prepare a student for the practical test with an FAA Designated Pilot Examiner (DPE). Training must fully comply with aeronautical experience, and the minimum hours requirement to complete training. Each license has privileges and limitations. The student pilot flies with their instructor predominately because the instructor is the Pilot in Command (PIC) who is responsible for the safety of the flight. To receive a Private Pilot license (PPL), the student must solo the aircraft in which they log PIC for 10 of the 40 hours of training. A PPL is only authorized to fly under VFR. An Instrument Student holds a PPL and is trained by a Certificated Flight Instructor – Instrument (CFII). Although the pilot is being trained to fly in Instrument Flight Rules (IFR), they are not authorized to fly in IFR unless a CFII is onboard and is responsible for the safety of the flight. Usually, a Commercial student holds a PPL and Instrument rating. Commercial students are trained by CFIs under Visual Flight Rules (VFR) and complete training with a minimum of 250 hours. A Certified Flight Instructor(CFI) must hold at least a Commercial Pilots License, and will only train student pilots for PPL, and CSEL students. The CFI can only be trained by a 2-year CFI under VFR. A CFII is an add-on to the CFI in most cases, a pilot can become a CFII before a CFI but will have to complete some training required for CFI, such as Fundamentals of Instruction (FOI). ATP is a pilot with a minimum of 1500 hrs. and is typically trained by the airline that hired the pilot for Pt. 121 scheduled passenger flight operations. In Table 3.2, the main licenses and ratings for the study are outlined and the type of weather flight conditions are trained to fly. Notice most of the licenses are visual flight rules.

Table 3.2 FAA Certification Training Requirements

FAA certifications Pt 61 Training	Training	Meteorological conditions
Student Pilot	Student in training with CFI to obtain PPL	Visual Flight Rules (VFR)
Private Pilot Certificate (PPL)	at least 40 hrs. of training by CFI	Visual Flight Rules (VFR)
Instrument Rating	at least 50hrs cross country training by CFII	Instrument Flight Rules (IFR)
Commercial Pilots License (CSEL)	250 hrs. total time trained by CFI	Visual Flight Rules (VFR)
Certified Flight Instructor (CFI)	at least CSEL trained by 2-year CFI	Visual Flight Rules (VFR)
Certified Flight Instructor-Instrument (CFII)	add on to CFI trained by CFII	Instrument Flight Rules (IFR)
Airline Transport Pilot	at least 1500hrs total time trained by Airline	Instrument Flight Rules (IFR)

Table 3.3 presents the total number of pilots in each category in 2016-2018. Additionally, the number of female pilots was also listed in the table. Among all the categories, commercial airplane pilots and airline transport pilots are also known as occupational pilots (as highlighted). The average total number of occupational pilots from 2016 to 2018 was 257,996, including 13,301 female occupational pilots.

Table 3.3 Number of Pilots (2016-2018)

CATEGORY	Total (Average 2016-2018)	Female only (Average 2016-2018)
Pilot--Total	**608,995**	**42,781**
Student	148,475	19,152
Recreational (only)	157	13
Sport (only)	6,077	231
Airplane		
Private	162,821	10,078
Commercial	98,041	6,301
Airline Transport	159,955	7,006
Rotorcraft (only)	15,302	
Glider (only)	18,167	

3.3.2 Age

To investigate the impacts of pilot age on the occurrence of CFIT accidents in General Aviation, the pilots were divided into 6 groups, which are under 20, 20-29, 30-39, 40-49, 50-59, and 60 and above. The age distribution is shown in Table 3.4.

Table 3.4 Age Distribution of Pilots (2016-2018)

Age Group	Total Number of Pilots	Percentage
under 20	17,214	2.83%
20-29	128,945	21.17%
30-39	111,738	18.35%
40-49	96,080	15.78%
50-59	115,691	19.00%
60 and above	139,326	22.88%
Total	608,994	1

The objectives of this research are: 1) to investigate the impacts of pilot-related factors on the occurrence of CFIT accidents in General Aviation, and 2) to recommend countermeasures to mitigate the CFIT accident risk in General Aviation. To achieve the first goal whereby a two-step approach was adopted. First, a descriptive analysis was conducted to present the characteristics of CFIT accidents in General Aviation. Next, a comparison study was performed to identify the groups of pilots who may have a high risk of involving a CFIT accident. The different groups that were investigated include age groups, male pilots vs. female pilots, and occupational pilots vs. non-occupational pilots.

Chapter 4. Data Analysis Results

This research study is conducted with two approaches, which are literature-based analysis and statistical analysis. Also, there were two types of analysis: descriptive analysis and a comparison study to determine if there is a cause-and-effect relationship between pilot-factors, and CFIT accidents from the sample size.

The literature review portion of this study outlines the existing recommendations on safety standards in the Aviation industry including the FAA, and other models adopted by the FAA. Furthermore, uncovering research outcomes from previous years on safety accidents in Aviation, and determining a correlation for current practices. Existing safety models were used to further investigate if the practices are being implemented by the General Aviation (GA) pilots in the study, due to the nature of individual pilot responsibility for safety of flight.

Statistical analysis was gathered from the 96 NTSB CFIT accidents in GA from 2016-2018, and a complete accident report was extracted to help determine the accident cause, and factors contributing to the accident. The NTSB is responsible for the investigative process and causation of the accident. Whereas, the FAA provides registered pilot data, distinguishing the pilots' individual history to further identify the pilot-related factors. This statistical data was imperative to the research outcomes because it allowed for a better understanding of a smaller data set that was used for this research.

4.1 Descriptive Analysis

This part presented the descriptive analysis results of CFIT accident data.

Total Number of Fatalities

Figure 4.1 shows the number of fatalities caused by each CFIT accident. Among the 96 accidents, 50 of them had no fatality, 25 of them resulted in 1 fatality, 11 resulted in 2 fatalities, 5 accidents resulted in 3 fatalities, 3 resulted in 4 fatalities, 1 resulted in 5, and 1 resulted in 16 fatalities.

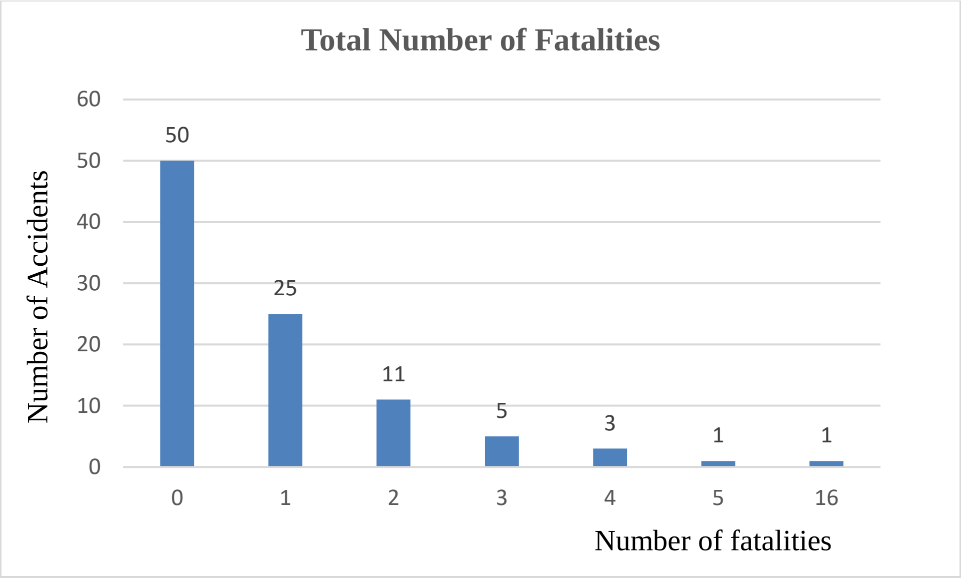


Figure 4.1. Total Number of Fatalities

Total Number of Serious Injuries

Figure 4.2 shows the total number of serious injuries caused by these 96 CFIT accidents. Most of these accidents had no serious injury. 13 accidents caused 1 serious injury, 9 accidents resulted in 2 serious injuries and 1 accident left 3 serious injuries.

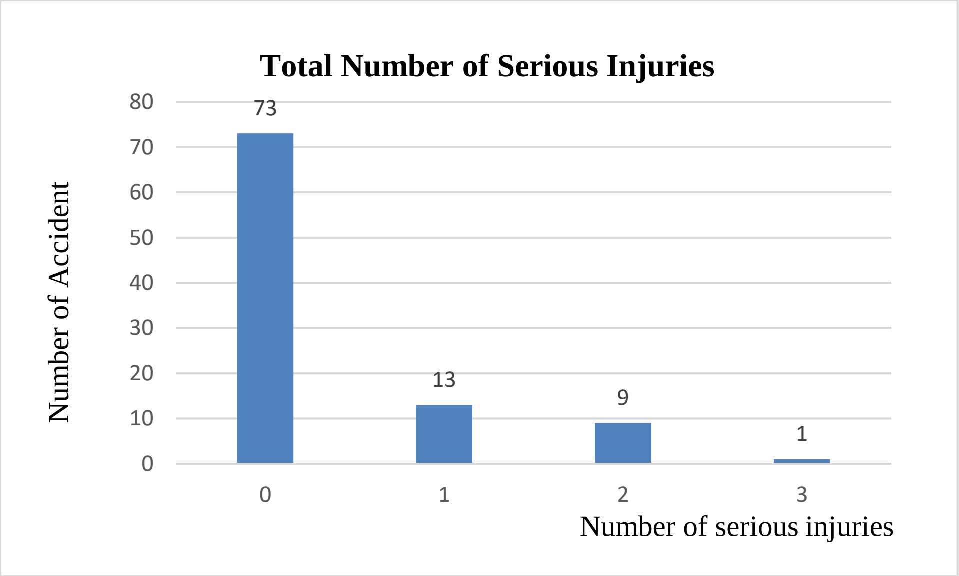


Figure 4.2. Total Number of Serious Injuries

Highest Injury Level

Figure 4.3 indicates the number of accidents with different highest injury levels. Among 96 accidents, 46 were fatal ones, 18 had serious injuries, 8 had minor injuries and 24 had no injury. The highest injury outcome is fatal for CFIT accidents due to the high impact of the aircraft resulting in complete hull loss. Almost half of CFIT accidents resulted in fatalities, which proves that CFIT accidents are one of three high-risk accident categories identified by the International Civil Aviation Organization.

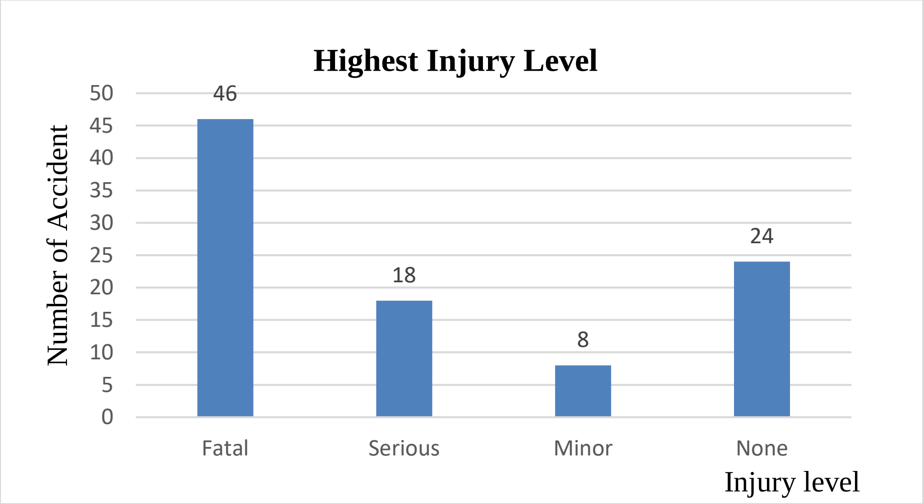


Figure 4.3. Highest Injury Level

Survival Rate Based on Damage to Aircraft

The three different types of damage categories are 1. Destroyed, 2. Substantial, and 3. None. Due to the controlled flight into terrain accident type, the aircraft at impact has a higher percentage of being destroyed or damaged substantially. An aircraft is typically only slowed during the landing phase of flight, the highest percentage of accidents were caused during phases of flight where the aircraft is at a higher speed measured in knots, and power setting measured in revolutions per minute. Due to the kinetic energy at impact, the aircraft has a smaller chance of remaining intact and saving the lives of the people onboard. In Figure 4.4, the destroyed aircraft has 100% fatalities with a total of 26 fatalities. Substantial has 20 fatal, 17 serious, 8 minor, and 24 none. None has 1 serious accident. Figure 21 shows the survivability rate based on accident type.

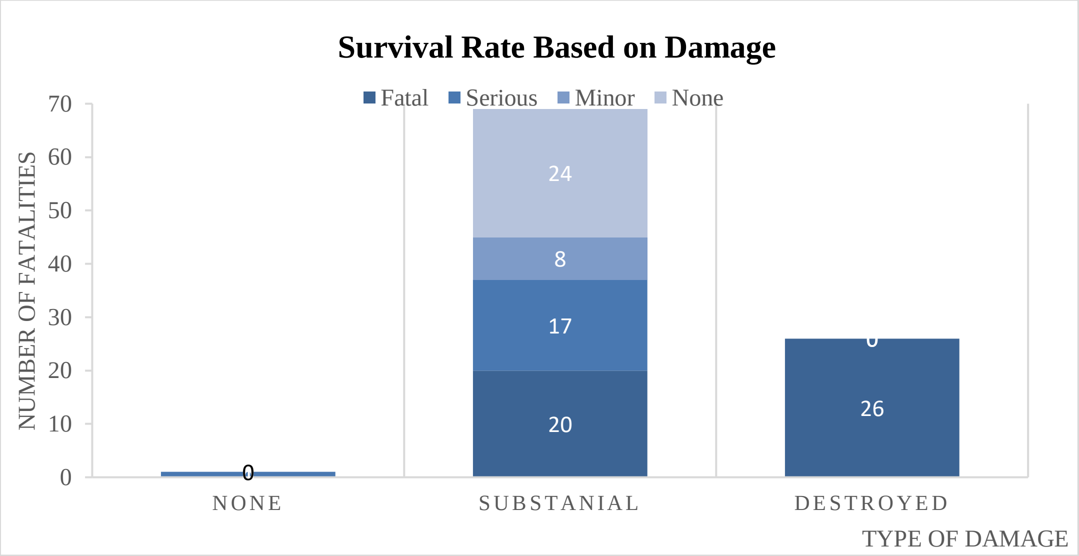


Figure 4.4. Survival Rate Based on Damage to Aircraft

Phase of Flight

The phase of flight is the phase associated with the defining event of the accident aircraft. The list and definition of each phase of flight can be found at: http://www.intlaviationstandards.org/Documents/PhaseofFlightDefinitions.pdf.

Figure 4.5 presents the phases of flight where those 96 CFIT accidents occurred, including 46 fatal accidents. In the approach phase 29 accidents occurred, 4 in the initial climb, 3 in emergency descent, 29 in enroute, and 30 occurred in maneuvering.

Accidents statistically occur more during different phases of flight, especially when the task of the pilot is higher. During the flight there is an extreme amount of multi-tasking while flying which typically requires aircraft maneuvering (climbing, descending, turning), take off (initial departure of the airport) and landing (descending aircraft preparing for landing) are task-saturated phases of flight. Phases of flight are significant for crash analysis across all safety accidents and can show significant contributions. Controlled Flight into terrain is the outcome of any aircraft that collides with a structure. The structures include but are not limited to powerlines, antennas, buildings, elevated terrain, bodies of water, trees, and ground.

According to Figure 4.5, the percentages of fatalities associated with the phases of Approaching (APR), En Route (ENR), and Maneuvering (MVN) were higher than that of the Initial Climb (ICL), and Emergency Descent (EMG). This data shows the high risk of these phases of flight in the event of CFIT accidents which statistically results in fatal crashes. It is significant to have a focus on phases of flight that could contribute to these results. The en route phase is an aircraft flying straight and level at a specific altitude above terrain based on the pilot’s planning to the intended destination. On the other hand, the approach phase is usually a descending aircraft from the en route altitude to prepare for landing at the intended landing destination. A maneuvering aircraft usually performs a variety of altitude, magnetic heading, and airspeed changes (climbs, turns, descents). This information can be found by flight data trackers and recorded by equipment in the aircraft.

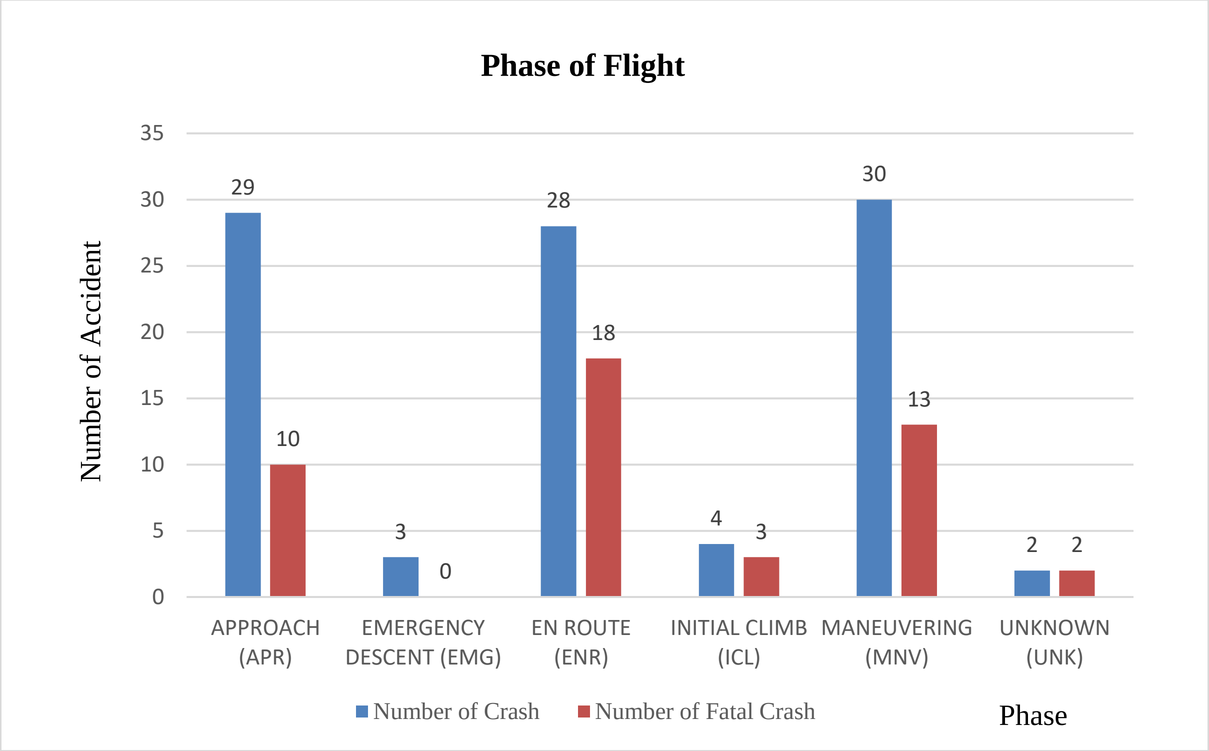


Figure 4.5. Phase of Flight

Illegal Act

An illegal act indicates if the accident flight involved an illegal act (such as suicide, sabotage, stolen aircraft, or terrorism). Figure 4.6 shows that among the 96 CFIT accidents that occurred in 2016-2018, 2 of them involved illegal acts.

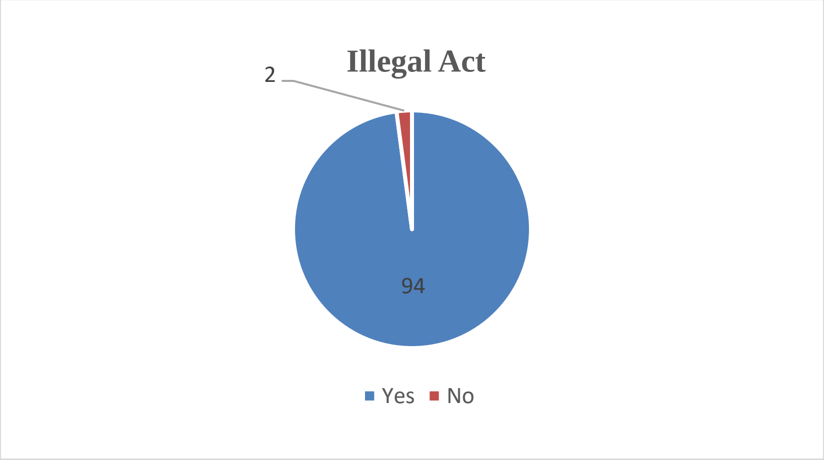


Figure 4.6. Illegal Act

Pilot Age

Figure 4.6 shows the number of CFIT accidents and fatal accidents caused by different age groups. It is obvious that pilots aged 60 and above accounted for most of the CFIT accidents in General Aviation.

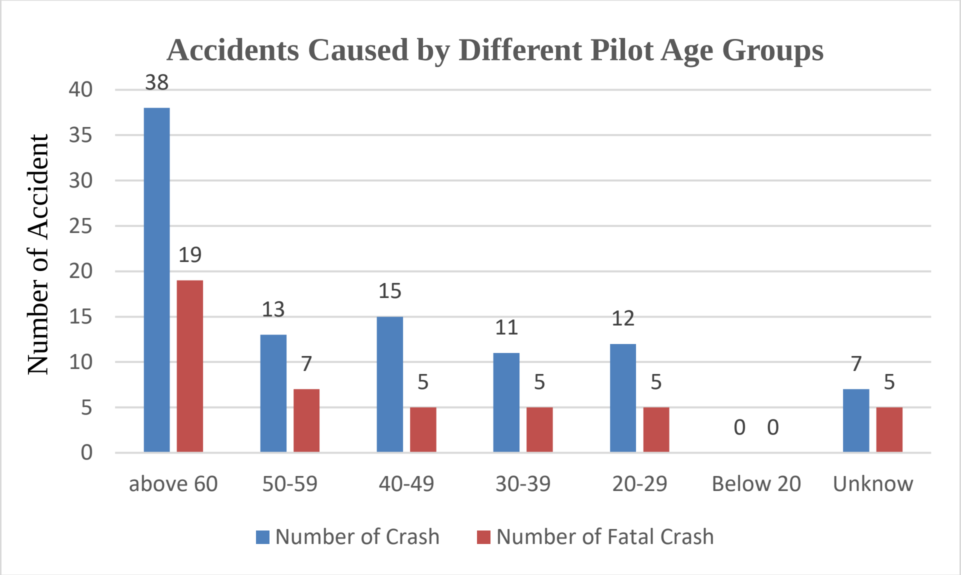


Figure 4.7. CFIT Accidents by Different Age Groups

Gender

Figure 4.8 is the Pilot's gender distribution of the collected 96 CFIT accidents. Among all 96 accidents, only one pilot was female.

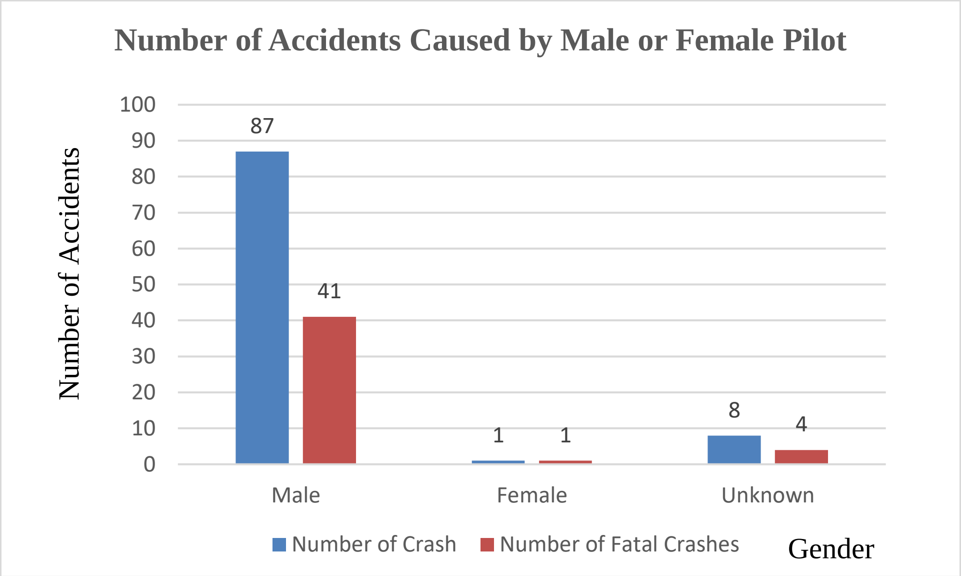


Figure 4.8. CFIT Accidents Caused by Different Gender

License

Another contributing factor is the type of license or rating and flight proficiency. Based on the collected data, 32.64% of the accidents were caused by private pilots which is the least amount of experience as it relates to a licensed pilot's licenses and ratings. However, this does not diminish flight hours as an experience. A pilot only professionally trained to fly in Visual Meteorological Conditions (VMC) cannot legally fly in certain weather types. CFIT crashes could be a result of inadvertently flying in adverse weather conditions in which the private pilot is not professionally trained by a Certified Flight Instructor-Instrument (CFII) and rated by the FAA by a Designated Pilot Examiner (DPE). Figure 4.9 shows the CFIT crashes caused by pilots with different licenses. It compares the accidents based on license or rating. The two highest categories were pilots holding a private license resulting in 35 accidents and commercial licenses resulting in 29.

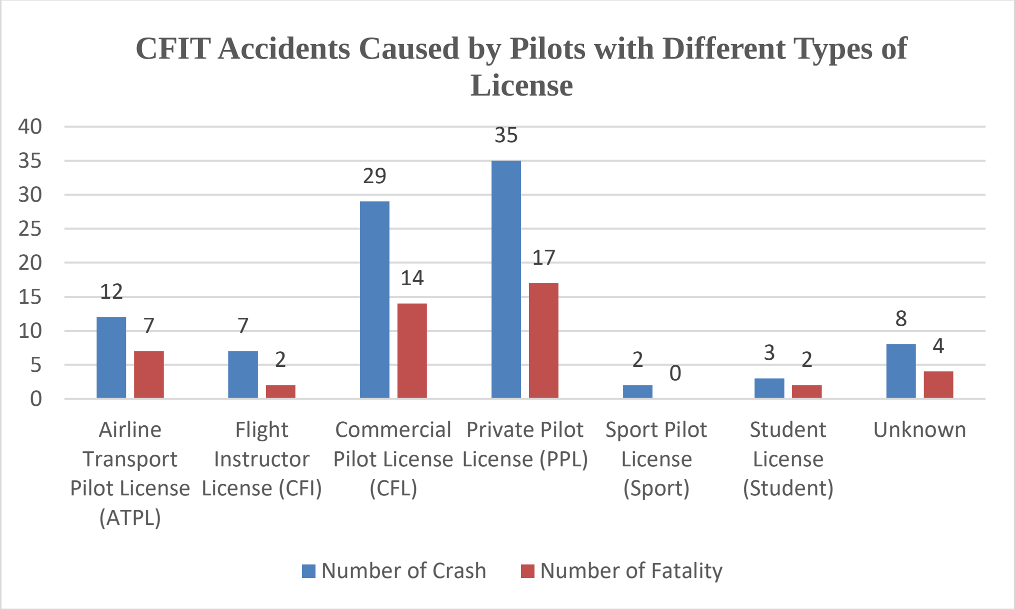


Figure 4.9. CFIT Accidents Caused by Pilots with Different Types of License

Medical

A medical certificate is required by the FAA for the pilots to ensure their health status is safe to fly. There are 1st Class, 2nd Class, and 3rd Class medical certificates as well as the newer Basic Med option. The 1st Class medical certificate has the highest requirements. Different medical certificates may be required for different types of pilots.

Figure 4.10 shows the medical certificate distribution among the 96 CFIT accidents in 2016-2018. Notice 2nd class, and 3rd class both caused a total of 33 accidents. As the pilot ages, the medical requirements become more extensive, and medical history could prevent a pilot from obtaining the highest class medical. In General Aviation, the medical required to fly is a 3rd class medical, which is the least restrictive of the three. Statistically, the majority of the accidents caused were by pilots with 3rd class medical and over 50 years of age. Medical certificates help determine the overall reported health of the pilots, which does affect their fitness for flying. Flying is strenuous and tedious requiring not only adequate day-to-day habits, but it also requires overall a healthy decision-making pilot who is more alert, and responsive to the very fast-paced environment.

A medical with limitations could be “must wear corrective lenses” or a limitation a little more serious preventing the pilot from operating the aircraft under certain medical limitations. This information obtained on the limitations was not consistently available for each dataset, only that a limitation was placed on the medical Based on the data collected the percentage of pilots and fatal accidents are presented by license against the number of accidents. Figure 4.10 also presents the fatalities of each medical certificate. The 3rd class with limitations had the highest number of CFIT accidents and the percentage of fatalities compared to total accidents is also high (57.89%).

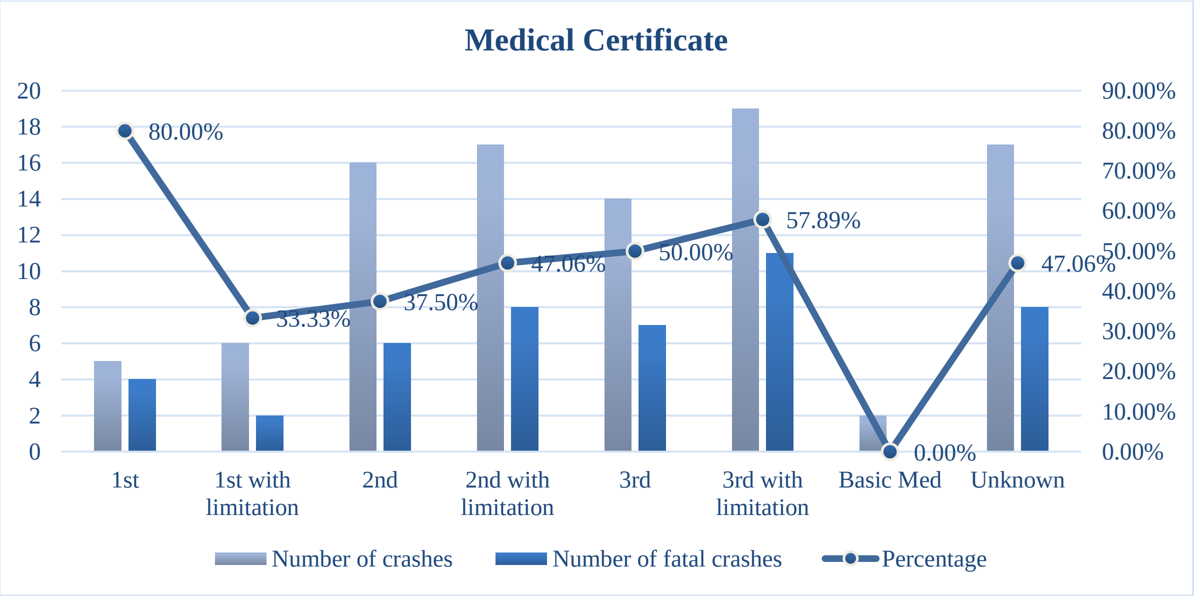


Figure 4.10. CFIT Accidents Caused by Pilots with Different Medical Certificates

Occupational Pilots

As previously mentioned, occupational pilots include commercial airplane pilots and airline transport pilots. Figure 4.11 shows the CFIT accidents caused by occupational pilots and non-occupational pilots. The pilots of most of the accidents were non-occupational.

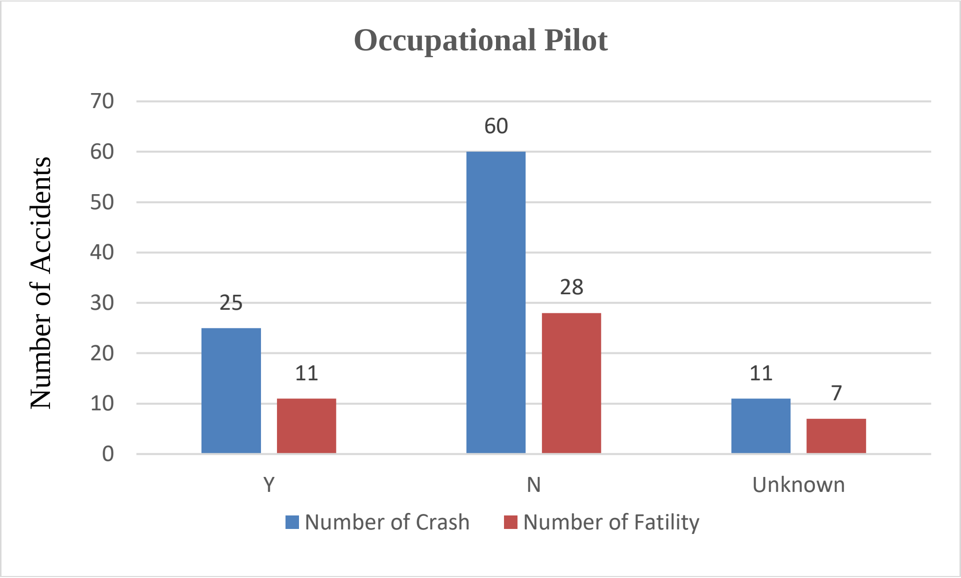


Figure 4.11. CFIT Accidents Caused by Occupational or Non-occupational Pilots

Second Pilots

Figure 4.12 presents whether there was a second pilot when the CFIT accident occurred. From the figure, we can see that most flights involved in CFIT accidents were operated by a single pilot.

This information is significant because while under Single Pilot Resource Management (SRM) and safety situations or health concerns become elevated in flight, the pilot has the sole responsibility to overcome these factors and still fly the plane safely. Single resource management is more common in General Aviation (GA). The aircraft are considered single pilot based on having a requirement of a single engine and under 12,000lbs. Often the pilots don’t need another pilot; however, it is beneficial to have another if the flight conditions become overwhelmingly difficult. Pilots are often plagued with over-task saturation. Based on the collected CFIT accidents in general aviation during 2016-2018, 68.2% of the accidents were caused by single pilot operations. In Figure 4.12, there were 72 accidents where the pilots were flying under SRM, and 14 accidents had 2 pilots operating under crew resource management (CRM).

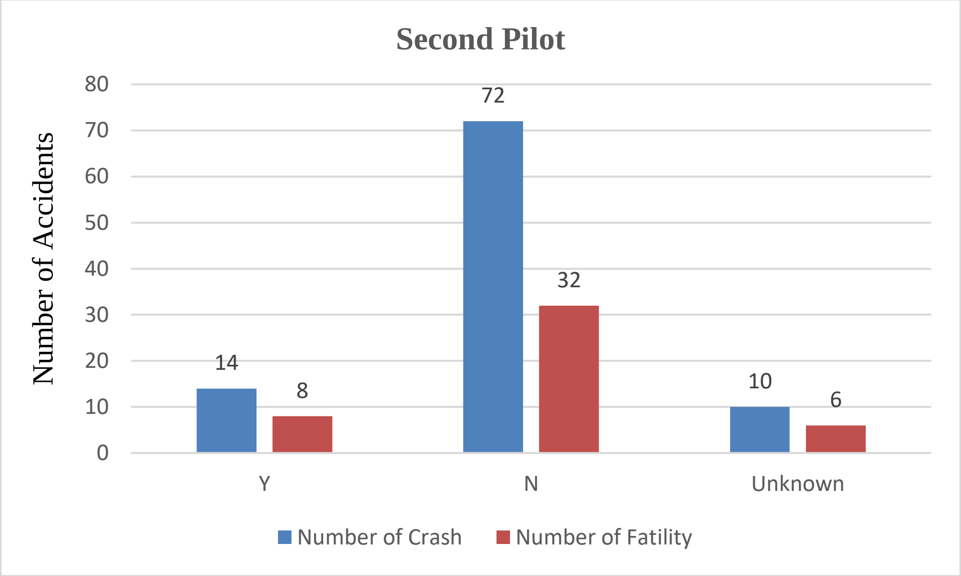


Figure 4.12. CFIT Accidents Caused by Single or Dual Pilots

4.2 Comparison Study

Different Age Groups

The pilots aged 60 and over were disproportionally involved in more CFIT crashes compared to other age groups. As shown in the following Figure 4.13, 22.88% of Pilots were age 60 or above in 2016-2018, and those pilots caused 42.70% of CFIT crashes for the same period.

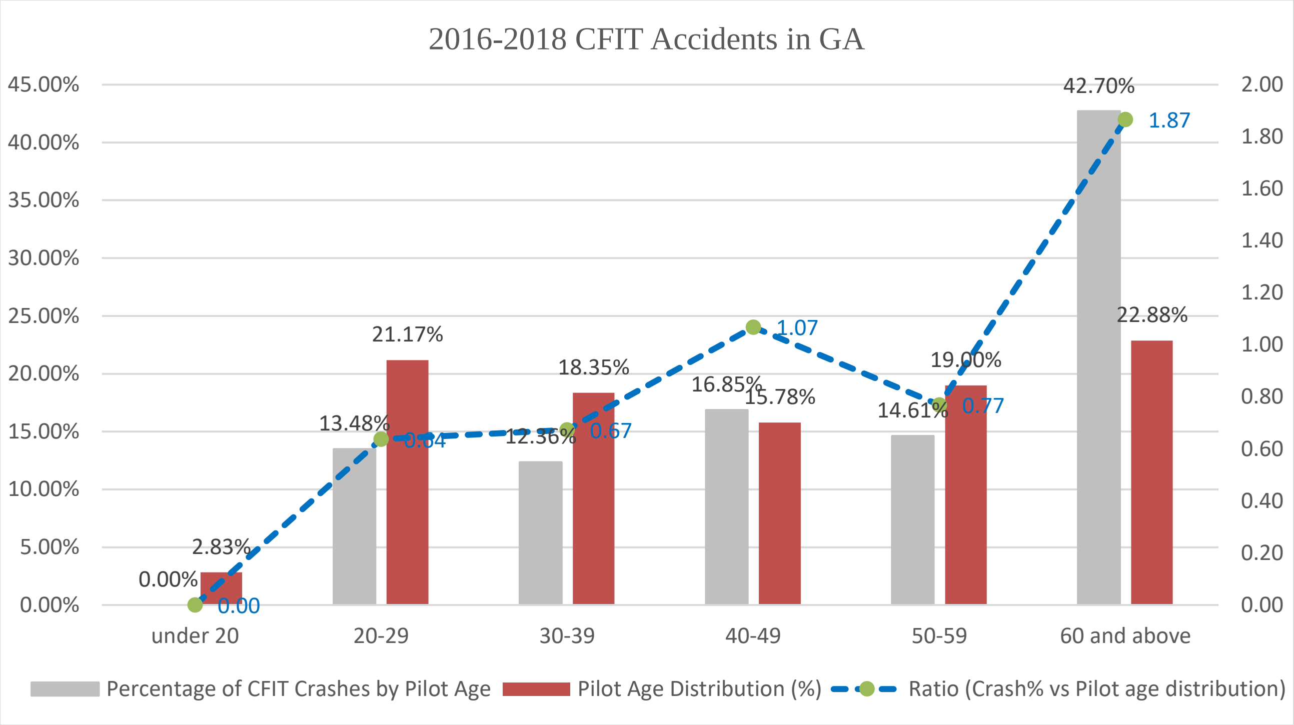


Figure 4.13. CFIT Crashes in Different Age Groups

Male Pilots vs Female Pilots

The male pilots were also disproportionally involved in more CFIT crashes compared to female pilots. As shown in Figure 4.14, in 2016-2018, 92.98% of the pilots were male and were accountable for 98.86% of the CFIT accidents in General Aviation.

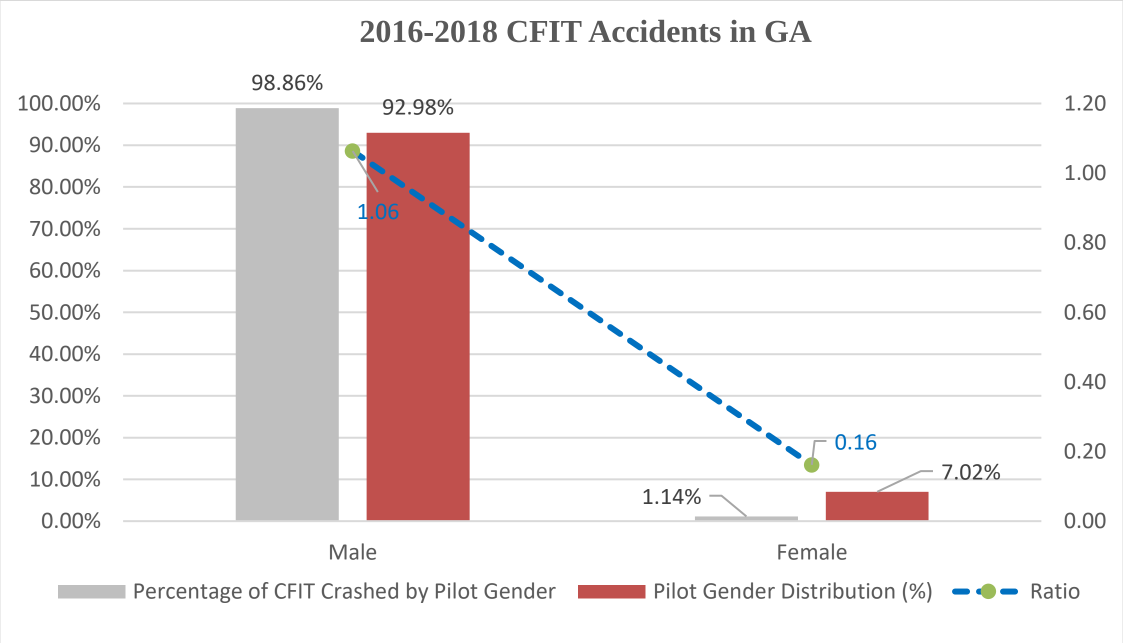


Figure 4.14. CFIT Crashes in Different Genders

Occupational Pilots vs Non-occupational Pilots

The same trend was found for Occupational Pilots and Non-occupational Pilots. The Non-occupational pilots were also disproportionally involved in more CFIT crashes compared to occupational pilots. As shown in Figure 4.15, 57.64% of the pilots were non-occupational in 2016-2018, but they caused 70.59% of all CFIT accidents in General Aviation.

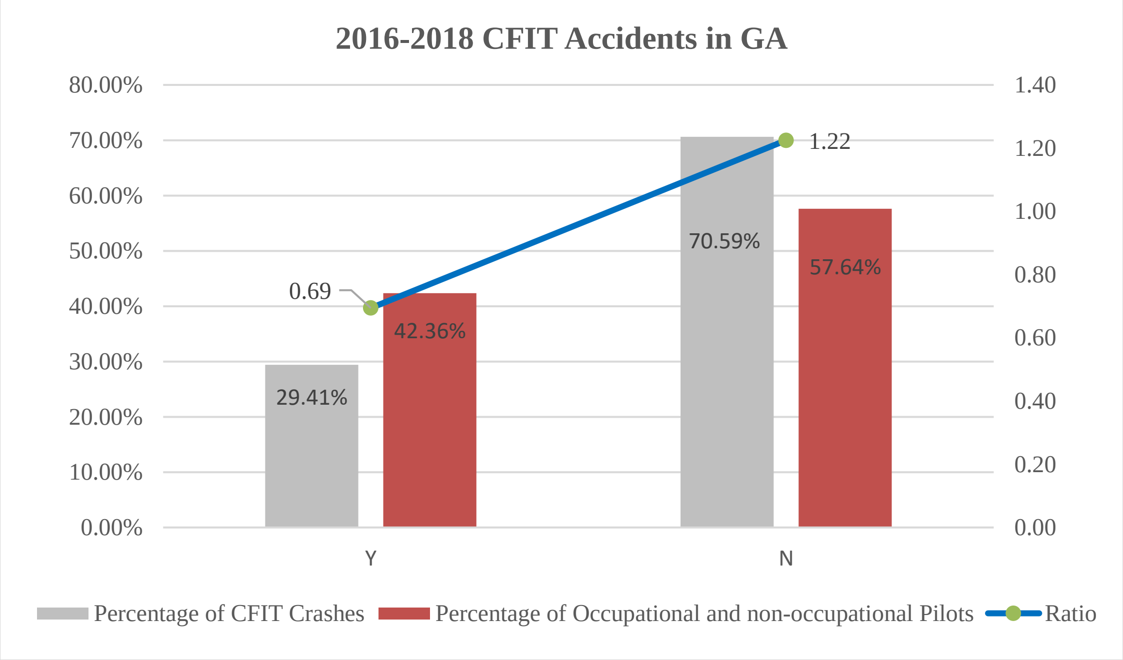


Figure 4.15. CFIT Crashes Caused by Occupational and Non-occupational Pilots

Chapter 5. Conclusions and Recommendations

5.1 Conclusion

CFIT accidents are more likely to result in irreversible damage to the aircraft leading to a higher likelihood of serious, and fatal injuries. This research study was done to investigate the pilot-related contributing factors for CFIT accidents in General Aviation (GA). To achieve this objective, 96 CFIT accidents that occurred in GA from 2016 to 2018 were analyzed and compared against each other to accurately identify the contributing factors. The following key tasks were conducted:

- Pilot-related factors were extracted to determine whether there were significant similarities present, which was determined to be true.
- Crash analysis data was collected from the individual crash reports that were generated by the NTSB which resulted in significant similarities in contributing to the accidents.
- Finally, the comparison of each accident using both pilot-related factors and crash analysis was conducted.

There were significant findings in this research regarding pilot-related factors. The following key findings were obtained from descriptive and comparison analysis of the collected CFIT accident data:

- The pilots aged 60 and over were disproportionally involved in more CFIT accidents compared to other age groups. 22.88% of Pilots were age 60 or above in 2016-2018, and those pilots caused 42.70% of CFIT crashes for the same period,
- The Non-occupational pilots were also disproportionally involved in more CFIT accidents compared to occupational pilots. 57.64% of the pilots were non-occupational in 2016-2018, but they caused 70.59% of all CFIT accidents in General Aviation,
- The pilots who hold a private license are involved in more CFIT accidents than the pilots who hold commercial licenses,
- The pilots who hold 3rd class medical certificates with limitations are involved in more CFIT accidents and the percentage of fatalities compared to total accidents is also high (57.89%).
- Most flights (72 out 96) involved in CFIT accidents were operated by a single pilot and a second pilot can significantly reduce the chance of CFIT accidents.
- The percentages of fatalities associated with the phases of Approaching (APR), En Route (ENR), and Maneuvering (MVN) were higher than that of the Initial Climb (ICL), and Emergency Descent (EMG).

Ultimately, the results will help determine higher-risk areas to focus on pilots in GA. Additionally, to develop new policies, and practices for improving the flight instructors' training and bi-annual flight reviews. Aviation is designed to constantly adjust to safer standards and procedures whereby safety is never compromised by nature. However, pilot-related factors have contributed to many accidents and complexities of human error.

5.2 Recommendations

Upon completion of this research study, viable recommendations were found for safety and efficiency. Recommendations to mitigate CFIT accidents in GA were determined to move cross-country more than 300 nautical miles under VFR. A current and Proficient Instrument pilot should be onboard in case inclement weather arises. The pilots are now working under crew resource management, instead of single pilot task saturated conditions.

5.2.1 Scenario-Based Training Modules Using Aviation Training Devices

Aviation Training Devices (ATD) are already commonly used during the training phases by Certified Flight Instructors (CFI), more sophisticated ATDs are helpful due to the ability to manipulate geographical location, weather conditions, aircraft type, simulated emergencies, and isolated failures. ATD training with instructors and students could be optimized with a customized safety crash prevention syllabus. Based on this research, some of the highlighted contributing factors for CFIT accidents can be prevented or mitigated in such syllabi:

- Extreme Task Saturation, and Crew Resource Management which does require a level of training and synchronicity, using scenarios that require a high workload.
- Weather deterioration (VMC to IMC) over a certain time frame (i.e., 20 minutes) to simulate more realistic conditions for the pilot to maintain a positive attitude aircraft, collect diversion airport information, complete checklist, brief passengers, communicate with ATC, and land the aircraft safely.
- Unusual attitude recovery at low altitudes or rising terrain conditions could increase the pilot's reaction time and practice unforgiving flight conditions in an ATD under a controlled environment.

5.2.2 **Existing Aircraft Equipment and Air Traffic Control**

A transponder is a wireless communication, monitoring, or control device that receives and automatically responds to incoming signals. Also, it is used in aircraft for detecting, identifying, and locating the aircraft on radar. Pilots use transponders to communicate with ATC as outlined in the literature review under existing recommendations. A distressed pilot could easily be identified by ATC with a set squawk code that falls under the same universal code identifiers in aviation.

Air Traffic Control (ATC) aircraft identification squawk (i.e., 7400) which could be inputted by the pilot or ATC based on pilot responses and qualifications. If they suspect the current weather conditions, rising terrain, or detectable pilot confusion help monitor and provide additional help to the pilot by utilizing the ATC.

5.2.3 **Policy Recommendations**

According to the findings of this research, the following Policy Recommendations were provided:

- Implement Mandatory Enhanced Training for Older Pilots: Given that pilots aged 60 and over are disproportionately involved in CFIT accidents, it is recommended that regulatory bodies and aviation organizations introduce mandatory recurrent training programs specifically tailored for older pilots. These programs should focus on situational awareness, decision-making under pressure, and the latest advancements in avionics that assist in terrain avoidance.
- Increased Oversight and Training for Non-Occupational Pilots: Since non-occupational pilots are more frequently involved in CFIT accidents, it is crucial to establish stricter training requirements and more frequent evaluations for this group. Additionally, creating specialized safety seminars and workshops that address the unique challenges faced by non-occupational pilots could help mitigate these risks.
- Review and Revise Certification Standards: The data suggests that pilots holding private licenses and those with 3rd class medical certificates with limitations are at a higher risk of CFIT accidents. It is recommended that certification standards be reviewed, with a potential increase in the stringency of medical and skill assessments for these categories. Furthermore, promoting the benefits of obtaining higher certifications (e.g., commercial licenses) could encourage pilots to pursue additional training and qualifications.
- Promote Two-Pilot Operations: with a significant reduction in CFIT accidents observed in flights operated by two pilots, aviation authorities should consider promoting or even mandating two-pilot operations for certain types of flights, especially in challenging environments or under poor weather conditions. This could be particularly beneficial for flights involving older pilots or those with private licenses.
- Focus on High-Risk Flight Phases: Since the highest percentages of fatalities are associated with the Approach, En Route, and Maneuvering phases, it is essential to enhance pilot training and procedural guidelines for these specific phases of flight. Implementing advanced avionics that provide better terrain awareness during these critical phases could also help reduce CFIT incidents.
- Strengthen Medical Certification Requirements: The higher involvement of pilots with 3rd class medical certificates and associated fatalities suggests a need for stricter medical evaluations. Aviation authorities should consider more frequent medical check-ups or the introduction of a more rigorous assessment process to ensure that pilots are physically and mentally fit to operate flights safely, particularly in complex environments.
- Annual Flight Review: Biannual Flight reviews are conducted for each pilot in GA typically by a CFI. However, since aviation is constantly evolving with safer procedures and recommendations to keep pilots safe, completing an Annual Flight Review will double the amount of time in the training environment. This will also

impact the pilot to remain proficient and up to date on newer technologies, procedures, and standards. This initiative could be partnered with insurance agencies in the future whereby promoting more pilots to stay abreast on safety enhancements.

These recommendations aim to address the identified risks and improve overall safety in General Aviation by focusing on the most vulnerable groups and high-risk scenarios.

Appendix

Private Pilot: A private pilot flies for pleasure or personal business without accepting compensation for flying except in some very limited, specific circumstances. The Private Pilot Certificate (PPC) is the certificate held by most active pilots. It allows command of any aircraft (subject to appropriate ratings) for any noncommercial purpose and gives almost unlimited authority to fly under VFR. Passengers may be carried and flight in furtherance of a business is permitted; however, a private pilot may not be compensated in any way for services as a pilot, although passengers can pay a pro-rata share of flight expenses, such as fuel or rental costs. If training under 14 CFR part 61, experience requirements include at least 40 hours of piloting time, including 20 hours of flight with an instructor and 10 hours of solo flight. (FAA, *Pilot's Handbook of Aeronautical Knowledge* 2016 Pg 1-17)

Private Pilot’s License Training Overview:

(FAA, *Aviation Handbooks & Manuals* 2021 Pg 1-1)

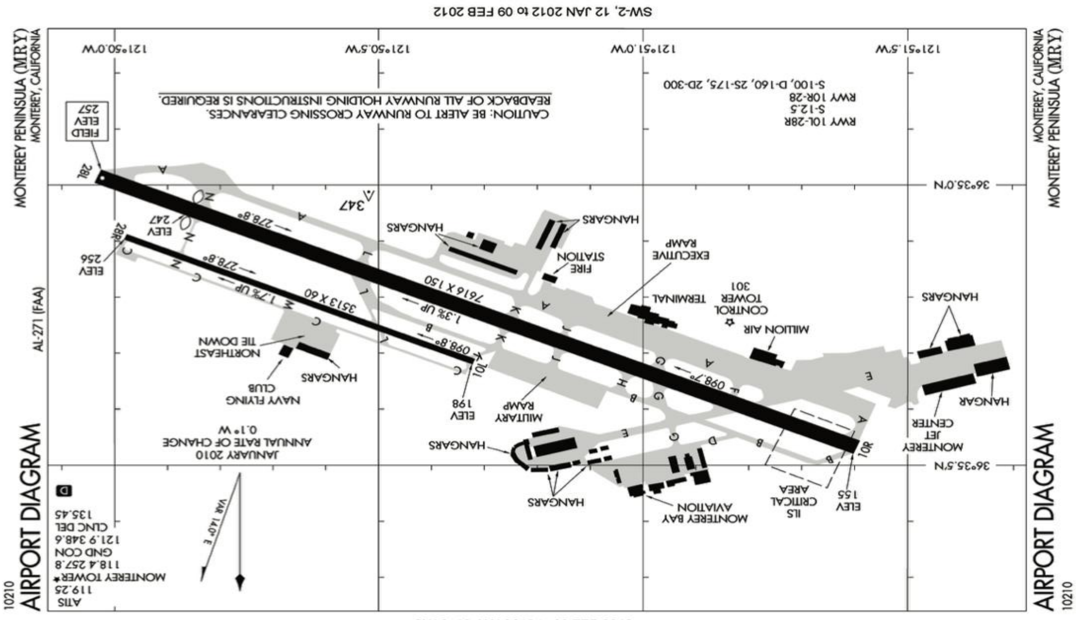
Commercial Pilot: A commercial pilot may be compensated for flying. Training for the certificate focuses on a better understanding of aircraft systems and a higher standard of airmanship. The Commercial Pilot Certificate (CPC) itself does not allow a pilot to fly in instrument meteorological conditions (IMC), and commercial pilots without an instrument rating are restricted to daytime flights within 50 NM when flying for hire. A commercial airplane pilot must be able to operate a complex airplane, as a specific number of hours of complex (or turbine-powered) aircraft time are among the prerequisites, and at least a portion of the practical examination is performed in a complex aircraft. A complex aircraft must have retractable landing gear, movable flaps, and a controllable-pitch propeller. See 14 CFR part 61, section 61.31(e) for additional information. (FAA, *Pilot's Handbook of Aeronautical Knowledge* 2016 Pg 1-18)

Pilots use checklists during flight to maintain situational awareness for each phase of flight.

Figure 1-17. *A sample checklist used by pilots.*

(FAA, *Aviation Handbooks & Manuals* 2021 Pg 1-16)

Airport Sample Airport Diagram providing information on airport layout and runway configurations: (cont. on following page)



(FAA, *Aviation Handbooks & Manuals* 2021 Pg 2-18)

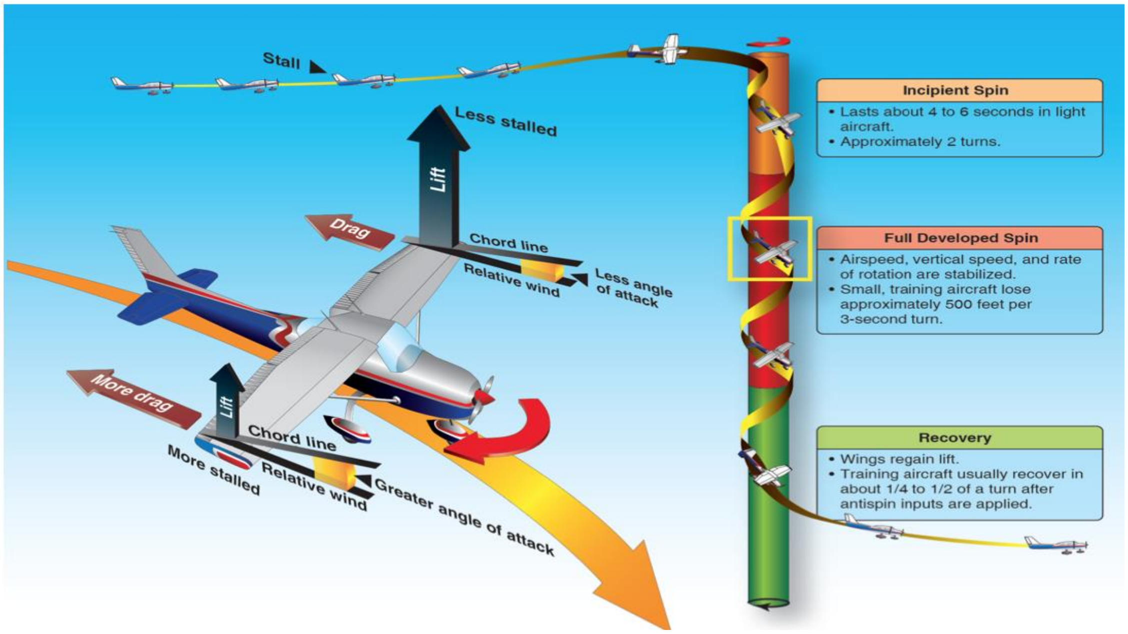
General Aviation flight controls and instrument panel with more sophisticated avionics:

(FAA, *Aviation Handbooks & Manuals* 2021 Pg 3-1)

Typical Instrument panel configurations:

FAA, *Pilot's Handbook of Aeronautical Knowledge* 2016 Pg 2-28)

Spin entry and recovery:



Incipient Spin

- Lasts about 4 to 6 seconds in light aircraft.
- Approximately 2 turns.

Full Developed Spin

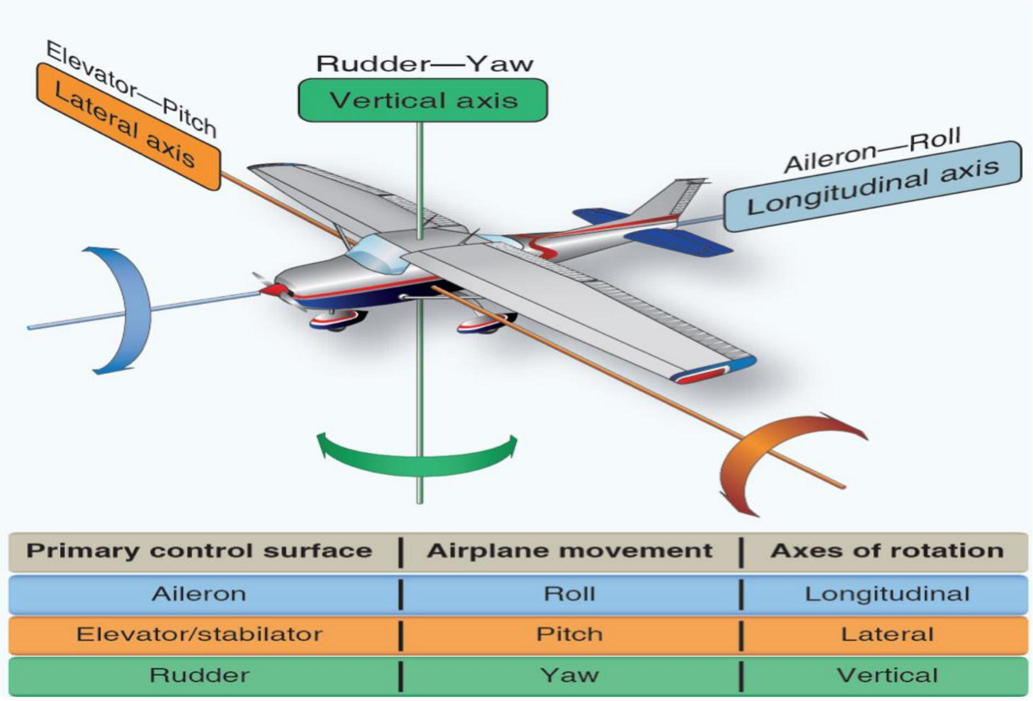
- Airspeed, vertical speed, and rate of rotation are stabilized.
- Small, training aircraft lose approximately 500 feet per 3-second turn.

Recovery

- Wings regain lift.
- Training aircraft usually recover in about 1/4 to 1/2 of a turn after antispin inputs are applied.

(FAA, *Aviation Handbooks & Manuals* 2021 Pg 5-23)

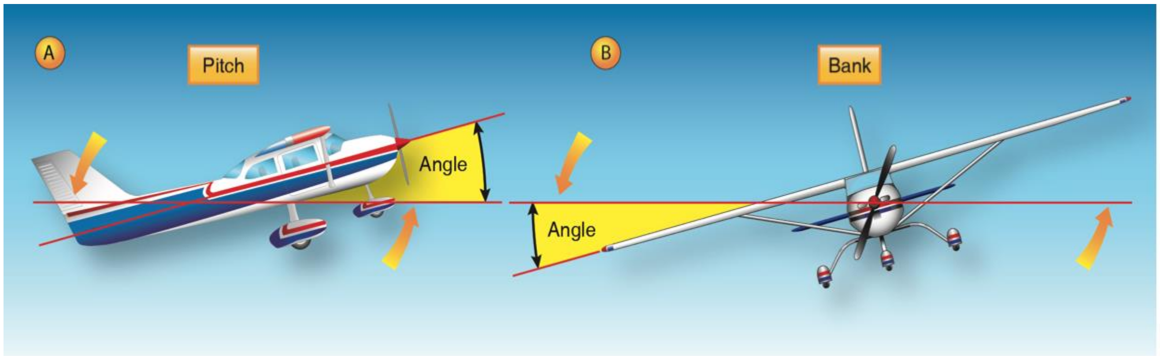
The Axis is which an airplane is controlled by the pilot:



Primary control surface	Airplane movement	Axes of rotation
Aileron	Roll	Longitudinal
Elevator/stabilator	Pitch	Lateral
Rudder	Yaw	Vertical

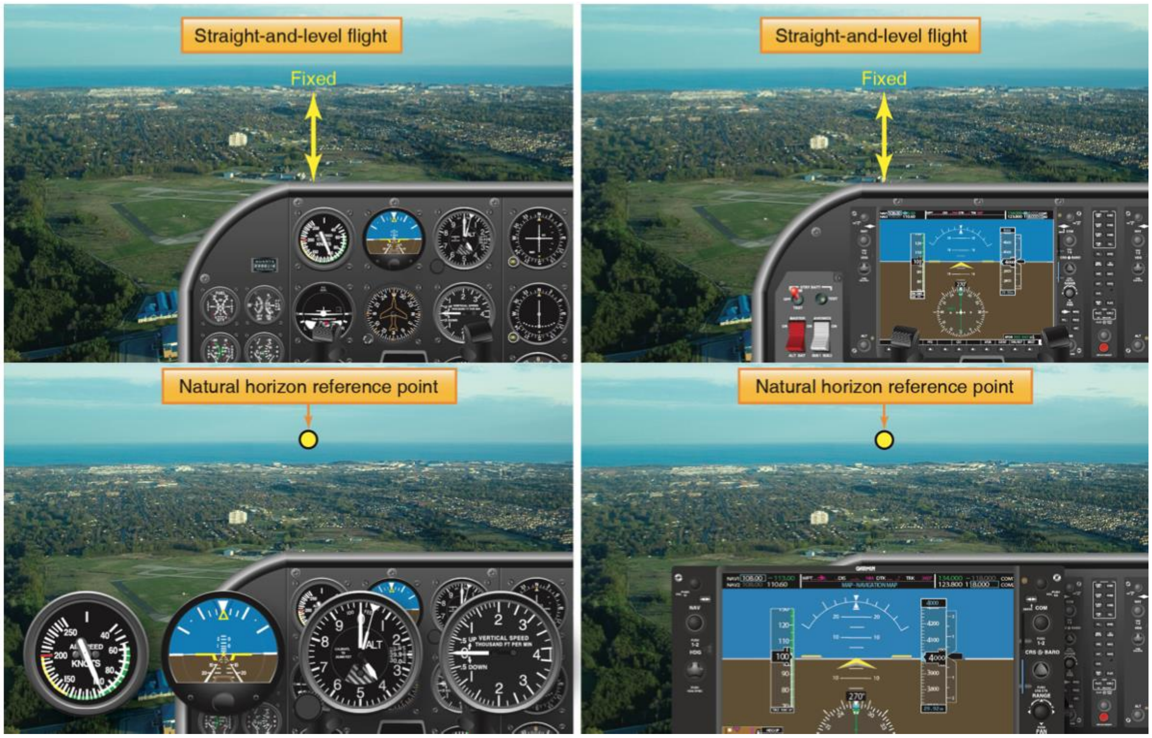
(FAA, *Aviation Handbooks & Manuals* 2021 Pg 3-2)

Reference to attitude flying:



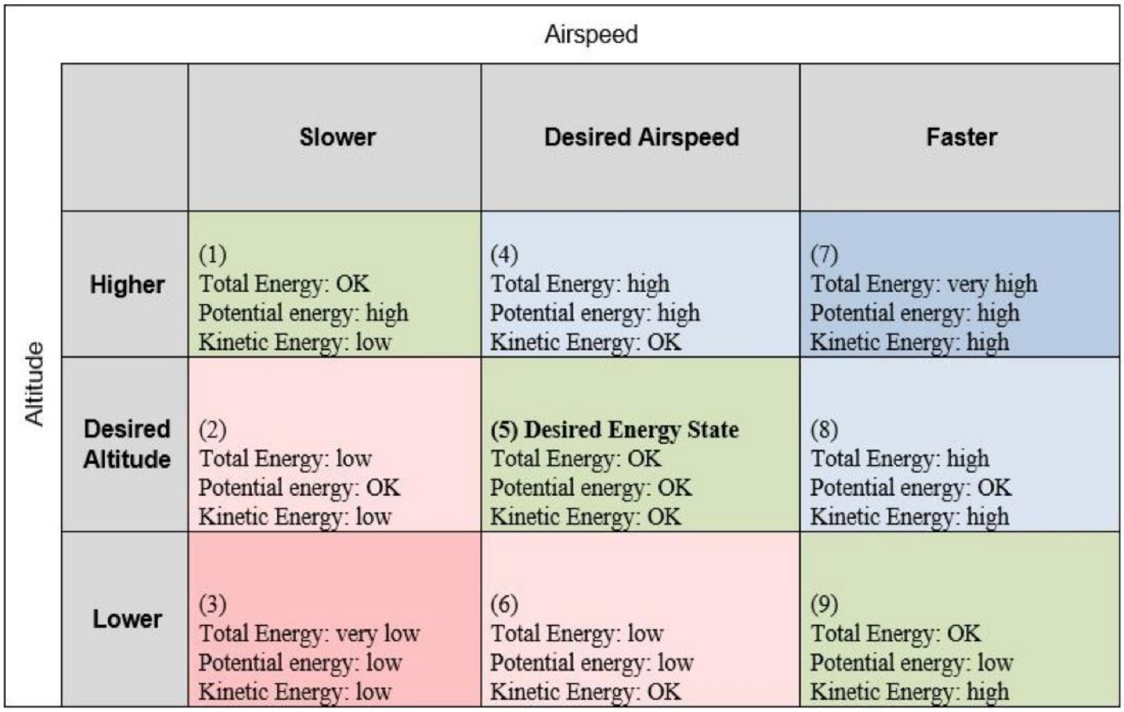
(FAA, *Aviation Handbooks & Manuals* 2021 Pg 3-4)

Reference to straight and level flight:



(FAA, *Aviation Handbooks & Manuals* 2021 Pg 3-7)

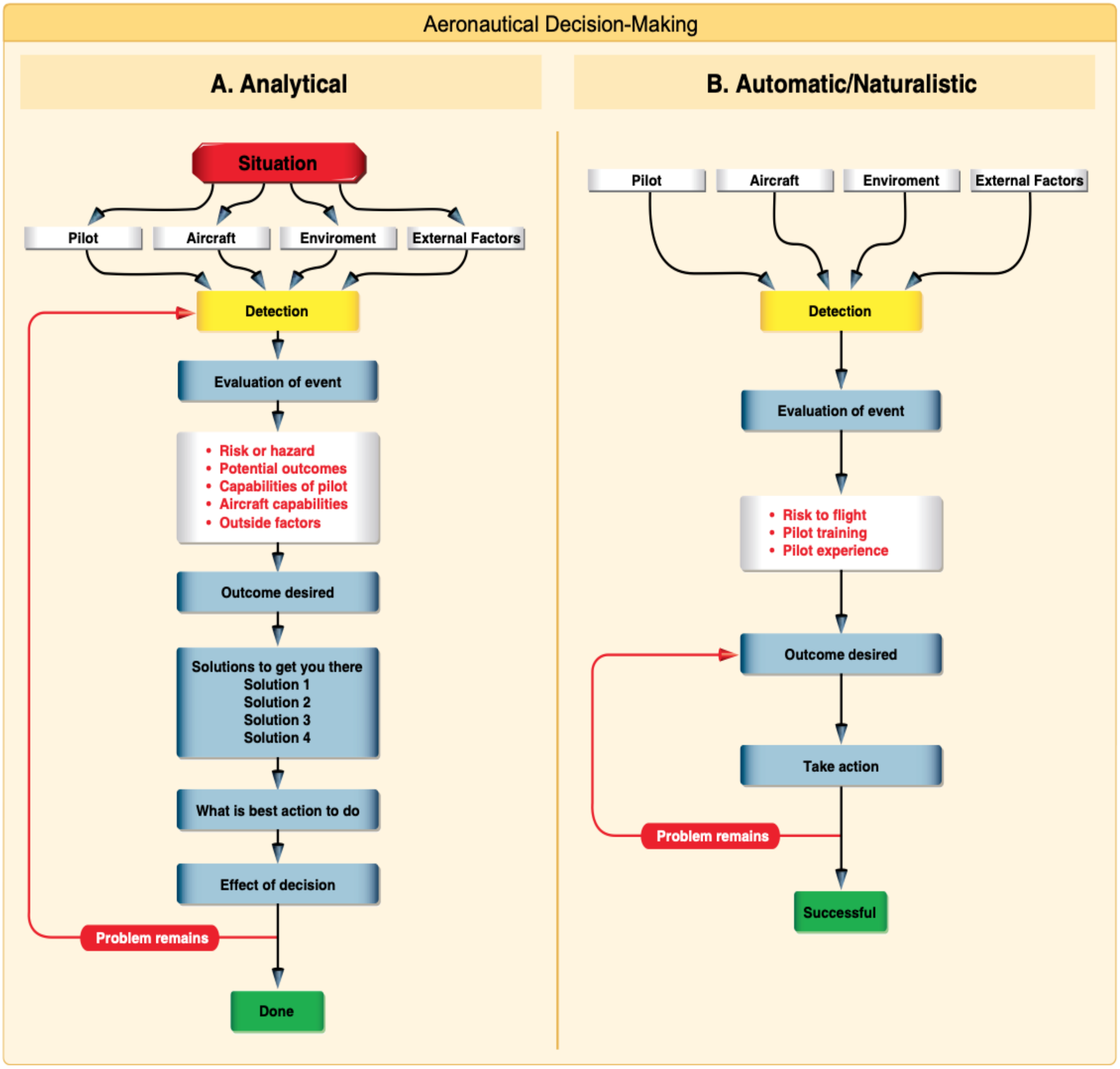
Energy state matrix for altitude and speed of the aircraft:

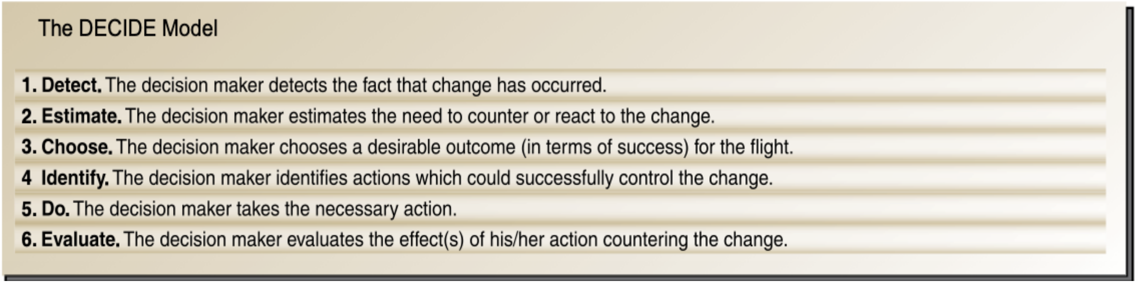


		Airspeed		
		Slower	**Desired Airspeed**	**Faster**
Altitude	**Higher**	(1) Total Energy: OK Potential energy: high Kinetic Energy: low	(4) Total Energy: high Potential energy: high Kinetic Energy: OK	(7) Total Energy: very high Potential energy: high Kinetic Energy: high
	Desired Altitude	(2) Total Energy: low Potential energy: OK Kinetic Energy: low	**(5) Desired Energy State** Total Energy: OK Potential energy: OK Kinetic Energy: OK	(8) Total Energy: high Potential energy: OK Kinetic Energy: high
	Lower	(3) Total Energy: very low Potential energy: low Kinetic Energy: low	(6) Total Energy: low Potential energy: low Kinetic Energy: OK	(9) Total Energy: OK Potential energy: low Kinetic Energy: high

(FAA, *Aviation Handbooks & Manuals* 2021 Pg 4-12)

Aeronautical Decision-Making Process:




The DECIDE Model

1. Detect. The decision maker detects the fact that change has occurred.
2. Estimate. The decision maker estimates the need to counter or react to the change.
3. Choose. The decision maker chooses a desirable outcome (in terms of success) for the flight.
4 Identify. The decision maker identifies actions which could successfully control the change.
5. Do. The decision maker takes the necessary action.
6. Evaluate. The decision maker evaluates the effect(s) of his/her action countering the change.

(FAA, *Aviation Handbooks & Manuals* 2009 Pg 5-2)

References

1. Aerospace, C. H. I. (2019, August 4). *How to read a METAR*. chiaerospace. Retrieved February 26, 2023, from https://www.chiaerospace.com/post/how-to-read-a-metar
2. Annex, Operation of Aircraft Part I, International Commercial Air Transport – Aeroplanes (9 ed.). International Civil Aviation Organization (ICAO). July 2010. pp. 1, 3 and 5. ISBN 9789292315368.
3. Aviators Guide. (2020, July 6). *Transponder and squawk codes*. Aviators Guide. Retrieved February 27, 2023, from https://aviatorsguide.wordpress.com/2020/07/06/transponder-and-squawk-codes/
4. *Aviation Handbooks & Manuals*. Aviation Handbooks & Manuals | Federal Aviation Administration. (2021). Retrieved February 27, 2023, from https://www.faa.gov/regulations_policies/handbooks_manuals/aviation
5. Benard, M. (2012). *The ACBS of atDs - Federal Aviation Administration*. FAA.gov. Retrieved February 18, 2023, from https://www.faa.gov/news/safety_briefing/2012/media/SepOct2012ATD.pdf
6. Bazargan, Massoud and Vitaly S. Guzhva. (2011). Impact of gender, age and experience of pilots on general aviation accidents. Accident Analysis and Prevention, 2011; 43: 962-970.
7. Chaparro, A., & Groff, L. (2002). *Human factors in aviation maintenance*. Human Factors in Aviation Maintenance | Federal Aviation Administration. Retrieved April 11, 2023, from https://www.faa.gov/about/initiatives/maintenance_hf
8. FAA. (2001). *Aviation Handbooks & Manuals*. Aviation Handbooks & Manuals | Federal Aviation Administration. Retrieved December 27, 2022, from https://www.faa.gov/regulations_policies/handbooks_manuals/aviation
9. FAA. (2009). *Aviation Handbooks & Manuals*. Aviation Handbooks & Manuals | Federal Aviation Administration. Retrieved February 27, 2023, from https://www.faa.gov/regulations_policies/handbooks_manuals/aviation
10. FAA. (2006). *Learning center library contents*. FAA Safety. Retrieved February 26, 2023, from https://www.faasafety.gov/gslac/alc/libview_printerfriendly.aspx?id=9091
11. Federal Aviation Administration (2012). Fact sheet-general aviation safety. Retrieved from http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=13672
12. FAA. (2016). *Pilot's Handbook of Aeronautical Knowledge*. Pilot's Handbook of Aeronautical Knowledge | Federal Aviation Administration. Retrieved March 1, 2023, from https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak
13. FAA. (2022). *AIM Section 6. Potential Flight Hazards*. Potential flight hazards. Retrieved March 1, 2023, from https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap7_section_6.html
14. *Fly the aircraft first - federal aviation administration*. Faa.gov. (n.d.). Retrieved March 2, 2023, from https://www.faa.gov/news/safety_briefing/2018/media/SE_Topic_18-07.pdf

15. Groucho, N. (n.d.). *Deterioration of pilot flight skills with age*. SKYbrary Aviation Safety. Retrieved October 22, 2022, from https://skybrary.aero/articles/deterioration-pilot-flight-skills-age
16. Kelly, D. & Efthymiou, M. (2019). An analysis of human factors in fifty controlled flight into terrain aviation accidents from 2007 to 2017. J Safety Res. 2019 Jun; 69:155-165. doi: 10.1016/j.jsr.2019.03.009.
17. IATA. (2016). *A Study of Terrain Awareness Warning System Capability and Human Factors in CFIT Accidents 2005-2014*. Iata.org. Retrieved December 23, 2022, from https://www.iata.org/contentassets/06377898f60c46028a4dd38f13f979ad/cfit-1st-edition.pdf
18. IATA. (2018). *CFIT – controlled flight into terrain - international air transport ...* iata.org. Retrieved December 25, 2022, from https://www.iata.org/contentassets/06377898f60c46028a4dd38f13f979ad/cfit-1st-edition.pdf (IATA, *CFIT – controlled flight into terrain - international air transport ...* 2018)
19. ICAO. (2018). *Threat and error management (TEM) in Flight Operations*. SKYbrary Aviation Safety. Retrieved February 14, 2023, from https://www.skybrary.aero/articles/threat-and-error-management-tem-flight-operations
20. Ladkin, P. (1997). Controlled Flight into Terrain: What is Being Done? Article RVS-J-97-08. http://www.rvs.uni-bielefeld.de/publications/Reports/CFIT.html#CFIT-and-Error
21. Matteson, R. C. (2001). *Controlled flight into terrain: How the airlines and the federal.* Controlled Flight into Terrain: How the Airlines and the Federal Aviation Administration are Addressing the Problem. Retrieved February 28, 2023, from https://commons.erau.edu/cgi/viewcontent.cgi?article=1282&context=jaaer
22. Mortimer, Rudolf G. (1991). Some factors associated with pilot age in general aviation crashes. Proceedings of the 6th International Symposium on Aviation Psychology, 1991, Columbus, OH. Pages 770-775.
23. Nall, J. T. (2010). *22nd Joseph T. Nall Report - Aircraft Owners and Pilots Association*. AOPA. Retrieved February 28, 2023, from https://www.aopa.org/-/media/files/aopa/home/training-and-safety/nall-report/11nall.pdf
24. NTSB. (2023). *The Investigative Process*. The investigative process. Retrieved March 1, 2023, from https://www.ntsb.gov/investigations/process/pages/default.aspx
25. Nuhu, N. S. (2019). Mitigating Risk Tolerance among General Aviation Pilots: Identifying Factors That Contribute to GA Pilots' Risk Perception. Daytona Beach. Retrieved from Aviation Science.
26. Shappell, S. A., Detwiler, C. A., Holcomb, K. A., Hackworth, C. A., Boquet, A. J., & Wiegmann, D. A. (2006). *Human error and commercial aviation accidents: A comprehensive, fine ...* Human Error and Commercial Aviation Accidents: A Comprehensive, Fine-Grained Analysis Using HFACS. Retrieved February 28, 2023, from

https://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2000s/media/200618.pdf

27. Summers, M. M., Ayers, F., Connolly, T., & Robertson, C. (2007, September). *Industry training standards (FITS)*. FAA. Retrieved February 18, 2023, from https://www.faa.gov/training_testing/training/fits
28. *The HFACS framework*. HFACS, Inc | The HFACS Framework. (2014). Retrieved February 27, 2023, from https://www.hfacs.com/hfacs-framework.html
29. *The "Swiss Cheese" model of human error causation (adapted from reason* ... (n.d.). Retrieved February 5, 2023, from https://www.researchgate.net/figure/The-Swiss-cheese-model-of-human-error-causation-adapted-from-Reason-1990_fig1_247897525
30. Thomas, T. et al. (2000). Controlled flight into terrain accidents among commuter and air taxi operators in Alaska. Aviat Space Environ Med. 2000 Nov;71(11):1098-103.
31. Wiener, E. (1977). Controlled Flight into Terrain Accidents: System-Induced Errors. Human Factors: The Journal of the Human Factors and Ergonomics Society. Volume: 19 issue: 2, page(s): 171-181
32. Woods, S. (2020). *Assessing if motivation impacts general aviation pilots' persistence in varying weather conditions*(dissertation). Daytona Beach, FL.