RISK ANALYSIS AND STANDARDIZATION
OF UNMANNED AERIAL VEHICLE
TRAINING REQUIREMENTS

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THESIS:  RISK ANALYSIS AND STANDARDIZATION OF UNMANNED AERIAL VEHICLE TRAINING REQUIREMENTS

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ABSTRACT

Progression in aviation began with manned flights in the Wright Flyer in 1903 and transitioned to modern unmanned drones flown by pilots halfway around the world by 2001. Various branches of the military and civilian contractors hired by the military fly unmanned drones. Inconsistencies in standards exist between civilian and military drone training where military drone pilots are not required to have the same flight hours and pilot license prerequisites when they start operating drones. There are safety concerns as civilian contractors to the military are held to a higher standard while military drone pilots have less training and experience.

Deming’s Plan-Do-Study-Act theoretical framework is used in conjunction with quality tools to find gaps in existing flight training programs. This study explores opportunities to reduce risks in the existing training programs to promote airspace safety and proposes a risk-based assessment with standardization for all unmanned drone pilot training.
CHAPTER 1

INTRODUCTION

Background

Manned airplanes first took flight in the early 1900s with flight times lasting a few seconds to a few hours. The Wright Flyer was constructed of spruce, the aerodynamic surfaces were covered with a finely woven muslin cloth and was propelled by a 12-horsepower four-cycle gasoline engine with an acceptable margin above the Wright brothers’ minimum design requirement of eight horsepower (Smithsonian National Air and Space Museum, n.d.a.). One pilot operated this simple airplane. The operation of the aircraft included the pilot lying down flat and moving his body to change the angle of attack of the wings to maintain balance or roll into a turn. Even though the flight was successful, the initial design exhibited poor pilot positioning and flight control ergonomics. Early flight training consisted of learning the winds, airplane control in straight flights to learning gentle turns based on balance.

Within 30 years, air flight went from the Wright Flyer climbing to 800 plus feet and flying for approximately 59 seconds to transatlantic and transpacific flights that carry cargo and passengers over thousands of miles. The events following the early years of aviation included modern commercial airliners with variable-pitch propellers for economical transit speeds and retractable landing gear to reduce drag and provide better take off performance. The Wright Flyer and transpacific and transatlantic flights were great achievements in the aerospace industry, but these were just the beginning. Figure 1 shows the development and growth of the aerospace industry over the past 100 plus years.
Figure 1

Development of Air Flight Over the Last 100+ Years

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1903</td>
<td>First powered, manned, heavier than air flight flown by Orville Wright (1)</td>
<td></td>
</tr>
<tr>
<td>1927</td>
<td>First, solo, nonstop, transatlantic flight flown by Charles Lindbergh (2)</td>
<td></td>
</tr>
<tr>
<td>1933</td>
<td>First, modern airliner Boeing 247 flown (3)</td>
<td></td>
</tr>
<tr>
<td>1947</td>
<td>First supersonic flight flown by Charles Yeager (4)</td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>First astronauts to walk on the moon—Apollo 11 (5)</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>Defense industry starts manufacturing &amp; testing unmanned aerial vehicles for military use (6)</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>UAVs used for combat in the aftermath of 9/11 (7)</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>US Air Force trains more UAV pilots than fighter pilots (7)</td>
<td></td>
</tr>
</tbody>
</table>


Aerospace technology has advanced to the point where airplanes can be flown without pilots (no humans onboard) halfway around the world. These unmanned airplanes are referred to as remotely piloted aircraft (RPA), drones, and unmanned aerial vehicles (UAV).

Before the addition of these sophisticated UAV, hobbyists and aviation enthusiasts experimented with radio-controlled (RC) airplanes that did not require much learning to fly. All
a hobbyist had to do was purchase an RC airplane, install the batteries, and have an undeveloped area to have fun. In the early stages, there were no certification or training requirements for a hobbyist to purchase and fly an RC airplane. Figure 2 displays RC airplanes commonly flown for recreation.

**Figure 2**

*Top Race RC Airplane and Traxxas Aton Quad Rotor Helicopter with Basic Specifications*

<table>
<thead>
<tr>
<th>(1) Top Race TR-C385 RC Plane</th>
<th>(2) Traxxas Aton Quad Rotor Helicopter</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Weight - 2 pounds</td>
<td>• Weight - 2 pounds</td>
</tr>
<tr>
<td>• Width - 21 inches</td>
<td>• Width - 18.5 inches</td>
</tr>
<tr>
<td>• Height - 5 inches</td>
<td>• Height - 8.5 inches</td>
</tr>
<tr>
<td>• Flight Radius - about 400 feet</td>
<td>• Flight Radius - about 500 feet</td>
</tr>
<tr>
<td>• Speed - 40 to 60 mph</td>
<td>• Speed - 50+ mph</td>
</tr>
</tbody>
</table>


An RC aircraft is a small flying machine that is controlled by an operator on the ground. The transmitter converts the pilot’s movements into a radio signal through a process called modulation and then broadcasts the signal to the receiver. The receiver inside the airplane picks
up the signal the same way the radio in a car picks up the local radio station. The receiver pulls the information from the radio waves and relays this information to the servos.

Each servo has a horn that is attached to its shaft. This horn is attached to a control surface, or engine throttle, via a push rod. The rotation of the horn translates into a linear movement at the control surfaces. The movement of the servo is directly proportional to the movement of the control sticks on the transmitter. In other words, the control surfaces on the airplane move exactly the way a person moves the stick on the transmitter (Brown, 2007/2020).

The transmitter and receiver operate on a common frequency in the megahertz zone. The transmitter and receiver must be on the same frequency channel to send and receive signals. The fewer channels the controller has, the less controllability of the airplane by the operator (e.g., one channel may control the motor or rudder whereas two or three channels would enable the operator to control the motor, elevator, and rudder). Two airplanes cannot fly on the same frequency at the same time.

Simple RC airplanes weigh one to two pounds and fly around in visual line-of-sight operations (between pilot and plane) with a range of about a couple hundred yards. A more interested operator may start by flying a simulator to get used to controlling the model airplane in a virtual setting and reduce the risk of damaging the model. More experienced operators upgrade their model airplanes in size and ability and even compete for titles. While this is on the hobby side, there is a whole other world to UAV and their use. In addition to a small (<55 pounds) simple UAV flown by a hobbyist for recreational use, UAV vary in size and can provide commercial services in multiple ways, including the following:

- intelligence, surveillance, and reconnaissance
- agriculture
- EMS surveillance support to first responders
- aerial photography and cinematography
- wildlife monitoring
- border patrol
- mapping and data collection

RC airplane design has progressed from small, lightweight, battery-powered to large scale, advanced propulsion systems equipped with high definition cameras, positioning data, and in some cases munitions for military use. Now, UAV can now fly higher and at longer ranges.

The common factor between the small RC airplanes and large-scale UAV is they all potentially fly in the same airspace. Increased interest in UAV has prompted the Federal Aviation Administration (FAA) to establish new regulations specifically for civilians flying UAV whether it is recreationally or commercially. New regulations promote best safety practices in the National Airspace System (NAS). The FAA does not require a certificate or license but does require that recreational small-scale drone flyers abide by:

1. Register the drone with the FAA and carry proof of registration.
2. Fly drones for recreational purposes only.
3. Follow the safety guidelines for a community-based organization.
4. Fly drone at or below 400 feet in uncontrolled or Class “G” airspace.
5. Do not fly in controlled airspace unless permission is granted through low altitude authorization and notification capability or flight at a recreational flyer fixed site that has written permission from the FAA.
6. Keep the drone within line of sight.
7. Do not fly in airspace where flight is prohibited.
8. Never fly near other aircraft, especially near airports.
9. Never fly over groups of people, public events, or stadiums full of people.

10. Never fly near emergencies such as any type of accident response, law enforcement activities, firefighting, or hurricane recovery efforts.

11. Never fly under the influence of drugs or alcohol (Federal Aviation Administration [FAA], 2020a).

Drone operators that want to fly small drones (55 pounds) for commercial use must obtain a Remote Pilot Certificate. Table 1 lists requirements that commercial users must comply with under the Code of Federal Regulations (CFR), Title 14, Chapter 1, Subchapter F, Part 107 Small Unmanned Aircraft Systems.

Table 1

<table>
<thead>
<tr>
<th>FAA Requirements for Obtaining Remote Pilot Certificate for Commercial Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certificated Remote Pilots Including Commercial Operators</td>
</tr>
<tr>
<td>Fly for work or business</td>
</tr>
<tr>
<td>Drone weighs &lt;55 pounds.</td>
</tr>
<tr>
<td>Follow Part 107 Guidelines</td>
</tr>
<tr>
<td>Review a summary of 14 CFR Part 107 rules</td>
</tr>
<tr>
<td>➢ Must be at least 16 years old</td>
</tr>
<tr>
<td>➢ Must be able to read, write, speak, and understand English</td>
</tr>
<tr>
<td>➢ Be in a physical and mental condition to safely fly a Unmanned Aircraft System (UAS)</td>
</tr>
<tr>
<td>➢ Schedule an appointment to take the Knowledge Test at an FAA-approved Knowledge Testing center.</td>
</tr>
<tr>
<td>➢ Pass Knowledge Test</td>
</tr>
<tr>
<td>Once test has been passed complete FAA Form 8710-13 for a remote pilot certificate</td>
</tr>
<tr>
<td>Final step: Register drone with the FAA</td>
</tr>
</tbody>
</table>

*Note. Created by the author of this thesis.*
Small drones used for recreational and commercial purposes are not the only ones that have an increase in interest. Government agencies, the United States (U.S.) Air Force (USAF), and the U.S. Army (USA) are the main organizations and military branches that use UAV regularly. The use of “USA” may be confused with the United States of America, but the U.S. Army acronym is “USA” and is used in this thesis. The USAF and USA primarily use large scale (>1,320 pounds) UAV in order to keep humans safely out of harm’s way, which increases justification to use unmanned airplanes. The UAV are useful because they can fly for extended periods of time—providing aerial surveillance with minimal breaks and without being seen or heard. Some models can fly more than 40 hours straight.

The ability to see over the next hill has long been the strategic move that ground troops have longed for. A safety and eye in the sky factor makes the use of drones very important. Figure 3 highlights General Atomics Aeronautical Systems, Inc. (GA-ASI) Predator B Remotely Piloted Aircraft used by the USAF.


Figure 3

Remote Piloted Aircraft Predator B Key Specifications

<table>
<thead>
<tr>
<th>General Atomics Predator B RPA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Altitude</td>
<td>50,000 feet</td>
</tr>
<tr>
<td>Max Endurance</td>
<td>42 hours</td>
</tr>
<tr>
<td>Max Airspeed</td>
<td>270 KTAS</td>
</tr>
<tr>
<td>Length</td>
<td>36 feet</td>
</tr>
<tr>
<td>Wingspan</td>
<td>79 feet</td>
</tr>
<tr>
<td>Max Gross Takeoff Weight</td>
<td>10,500 pounds</td>
</tr>
<tr>
<td>Fuel Capacity</td>
<td>3,900 pounds</td>
</tr>
</tbody>
</table>


Military UAV fly in designated airspace and are operated by military operators and civilian contractors. Most civilian operators contracted to fly with the military must hold a manned FAA commercial pilot license and must have a minimum amount of pilot-in-command (PIC) hours, which depends on an organization’s requirements. A pilot must obtain a manned private pilot license before pursuing a manned commercial pilot license. Table 2 illustrates the minimum requirements for obtaining a manned private and commercial pilot license.
### Table 2

**Pilot Certificate Requirements Under 14 CFR Part 61**

<table>
<thead>
<tr>
<th>Flight Experience-Airplane Single Engine Rating-Private Pilot</th>
<th>Part 61</th>
</tr>
</thead>
<tbody>
<tr>
<td>Must be 17 years old. Must be able to read, speak, write, and understand the English language.</td>
<td></td>
</tr>
<tr>
<td><strong>Minimum Aeronautical Experience</strong></td>
<td><strong>Part 61</strong></td>
</tr>
<tr>
<td>Total Time</td>
<td>40 hours</td>
</tr>
<tr>
<td>Dual Instruction</td>
<td>20 hours</td>
</tr>
<tr>
<td>Instrument Instruction</td>
<td>3 hours</td>
</tr>
<tr>
<td>Solo Flight Time</td>
<td>10 hours</td>
</tr>
<tr>
<td>Night Flying</td>
<td>3 hours</td>
</tr>
<tr>
<td>Cross Country</td>
<td>3 hours</td>
</tr>
<tr>
<td>Solo Cross Country</td>
<td>5 hours</td>
</tr>
<tr>
<td>Cross Country Distances</td>
<td>1 flight 100 nm distance</td>
</tr>
<tr>
<td>Solo Cross Country</td>
<td>1 flight 150 nm with 3 stops</td>
</tr>
<tr>
<td>Take Off/Landings Night</td>
<td>10 full stop landings</td>
</tr>
<tr>
<td>Take off/Landing at controlled tower</td>
<td>3 takeoff/full stop landings</td>
</tr>
<tr>
<td>60 days prior to flight Test</td>
<td>3 hours with instructor</td>
</tr>
</tbody>
</table>

**Flight Experience-Airplane Single Engine Rating-Commercial Pilot**

<table>
<thead>
<tr>
<th>Must be 18 years old Must be able to read, speak, write, and understand the English language. Logbook endorsement from authorized instructor. Pass required knowledge test. Pass required practical test. Hold at least a private pilot certificate. Demonstrates aeronautical knowledge of applicable areas that pertain to aircraft category.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minimum Aeronautical Experience</strong></td>
</tr>
<tr>
<td>Total Time</td>
</tr>
<tr>
<td>Powered aircraft/airplane Time</td>
</tr>
<tr>
<td>Pilot in Command (PIC) Time</td>
</tr>
<tr>
<td>Cross Country Time as PIC</td>
</tr>
<tr>
<td>Instrument Training Time</td>
</tr>
<tr>
<td>Complex Airplane Time</td>
</tr>
<tr>
<td>Cross Country Time-Day/100nm</td>
</tr>
<tr>
<td>Practical Test Flying w/Instructor</td>
</tr>
<tr>
<td>Solo Flight Time</td>
</tr>
<tr>
<td>Cross Country Flight &gt;300nm</td>
</tr>
<tr>
<td>Night Flying 10 takeoff/landings</td>
</tr>
</tbody>
</table>

*Note.* One nautical mile (nm) = 1.15078 mile = 1852 meters. Created by the author of this thesis.

As shown in Table 2, in order to obtain a manned commercial pilot license, flight experience and hour requirements are significantly increased from what a private pilot is required to obtain. Although the requirements for civilian operators have been stricter, military
operators have a varying level of requirements and ability that depends on military branch, operations, and required functions. The unsuccessful part about the varying level of operator ability is UAV crashes that continue to be a problem, and human factors are among the top reasons for the accidents.

**Statement of the Problem**

Human factors are issues affecting how individuals do their jobs. Human factors are social and personal skills like communication and decision making, which complement our technical skills. The combination of these skills is paramount for safe and efficient aviation. Human factor issues that are specifically tied to human errors contribute to more aircraft incidents and accidents than any other single factor. Human errors include errors by the flight crew, maintenance personnel, and air traffic controllers among others, who have a direct impact on flight safety (National Research Council, 1998).

Given the increased interest in UAV, the FAA is researching how to integrate more UAV into the NAS and not just in restricted airspace. Integrating UAV into the NAS where civilians fly for work or pleasure can be a dangerous environment if not integrated properly. The initial emphasis needs to be on pilot training. Classroom training, simulator training, and flight training with a qualified pilot instructor establish a foundation. Aviation weather and aerodynamic effects on an airplane while airborne is imperative for understanding how these factors all contribute to and affect flight are thoroughly reviewed and tested in initial manned pilot training.

Pilot errors and how they can be corrected has been researched, but accidents due to human factors are still seen. The skill level in piloting UAV can vary drastically. The unfortunate part is the variance has not been regulated for operators that want to fly UAV in civil airspace. The upcoming integration of UAV into the civil airspace can include small-scale drones that
weigh less than 55 pounds and are operated by a single remote control and visual line-of-sight transmission signals up to large-scale UAV that can weigh up to 12,500 pounds and are operated by satellite communications from hundreds of miles away. The skill level of interested civilian drone operators can range from a general interest in remotely piloted drones to a professionally and commercially licensed pilot with thousands of hours of manned flight time. The military does not have this same training and experience requirements. Since the range can vary drastically, there is potential for a hazardous environment that can cause serious accidents that result in loss of lives.

Conducting risk-based analysis on current UAV pilot training is going to be a step forward in finding the root cause of the problem that includes accidents due to human factors. To understand why these accidents occurred, this study has used the findings of accident reports and other primary sources to perform a risk-based analysis of UAV crashes due to human factors. This analysis also has focused on questions that need to be answered regarding the primary human factors that result in UAV crashes. Also, solutions are proposed and analyzed to prevent or avoid the occurrence of these factors.

**Purpose of the Study**

The aerospace industry has come a long way since the Wright Flyer flew in 1903. Technological advancement is crucial and is happening more rapidly than ever before. Risks still exist with technological advancements. Society relies on these advances, but they should not come at the cost of safety. Aerospace scholars, military research labs, and the FAA have done many studies about unmanned aircraft, their inclusion, and why they fail. These studies have concentrated on the number of crashes and the reason for the crash. The categories that have been established include the following:
- mechanical failure
- engine failure
- human factors pilot error
- communication problems

Human factors and mechanical issues top the list of why UAV crash. Mechanical issues can be ruled as an uncontrollable failure not due to the operator. Human factors are ruled as pilot error and easily dismissed, but they should not be. Inconsistencies exist in standards between commercial and military drone pilots that introduce human factor risks associated with one group of drone pilots being required to have a pilot certificate and another group that is not required to have this training or flight experience.

The purpose of this study was to use quality tools to investigate a probable root cause for the human factor errors in flying UAV starting with pilot training and propose a solution to combat the problem.

Since human factors top the list of why the majority of UAV crash, the need for further analysis exists. By conducting root cause analysis (RCA) of UAV crashes due to human factors, one can identify (1) which human factors can be addressed for change, and (2) which factors cannot be addressed due to an isolated incident or the inability to be recreated (Doggett, 2005). This would be a step forward in finding a solution for the human factor causes that can be taught at the pilot training level and establish an environment of awareness for known human factor issues when piloting UAV.

Without finding the root cause of the failure, the efforts would be unproductive, unrewarding, and continue to damage the UAV community. The study, which is the focus of this thesis, investigated and analyzed training standards established by the FAA and the military
determined to be sufficient for avoiding plane crashes. As a result, this study proposed an analysis and recommendation that all UAV pilots meet manned aircraft training standards by obtaining a commercial pilot license before flying UAV.

**Theoretical Basis and Organization**

Most individuals who are familiar with UAV are unaware of the requirements to operate one. Individuals that have never flown a manned airplane believe flying UAV is easy or like playing a video game. Most individuals do not realize UAV have more advanced technology, capabilities, and can exceed the size of general aviation airplanes. UAV pilots must be trained by standardized requirements to become the safest operators in the UAS environment.

Deming’s Plan-Do-Study-Act (PDSA) theoretical framework was used to identify gaps in existing flight training programs. The theoretical framework was used in this study to identify areas for improvement using quality tools that would allow organizations to reduce accidents and improve safety. PDSA was useful at disseminating process information into prosecutable steps, assessing the results, improving the process, and testing the process again (Deming, 1982). Utilization of continual PDSA cycles established continuous improvement progression of process improvement investigations.

The PDSA is a continuous improvement cycle that originated from the Shewhart cycle (Deming, 1994). The PDSA framework excels across many disciplines by enabling systems to make the right decision based on information (Moen, 2009; Moen & Norman, 2010). The four stages of the PDSA cycle continuous learning and improvement framework are as follows:

- **The Plan phase** establishes opportunities to make changes aimed at improvement and introduces a brief statement of the plan that needs to be tested. The purpose is defined with questions and predictions. A review of current processes and potential causes of problems are identified. Communication of the scope of the study with the research team ensures that the plan remains consistent with goals and objectives. The three
fundamental questions and the respective answer, that determines the basis for improvements about this study are as follows:

1. **What are we trying to accomplish?**
   
a. We are trying to accomplish standardized training requirements for all UAV pilots to reduce human factors accidents. This study has addressed the root causes of UAV accidents resulting from human factors. By identifying the root causes, and understanding the effects, a proposal can be developed to standardize UAV pilot training and improve safety.

2. **How are we going to know that a change is an improvement?**
   
a. We are going to know the change is an improvement when we see an increase in performance and reduction in human factors errors.

3. **What changes can we make that will result in an improvement (Langley et al., 1994)?**
   
a. We can transform UAV organizations into a collaborative group focused on NAS Safety.
   
b. We can implement new standardized training requirements for the UAS industry.

The following quality tools were identified during the Plan phase as most useful for supporting the implementation of the Model for Improvement, including: strengths, weaknesses, opportunities, and threats (SWOT) analysis, failure modes effects analysis (FMEA), affinity diagram, and RCA.

- **The Do phase** included conducting a change or test by observing, measuring, and capturing data during implementation. The Do phase in the PDSA carried out the research plan, documented results, and displayed how information was collected. This phase included a description of how UAV pilots are currently being trained and the risks of the human factor associated with non-standardized training among the authorized operators. Concurrently, an examination of standardized manned training was conducted to discover potential data sharing and techniques to implement in the UAS community for process improvements.

SWOT analysis was used to document internal and external factors pertaining to UAV use. FMEA was used to document failure modes and effects to identify the biggest risks. An affinity diagram was used to group ideas related to a problem and organize them into categories by their natural relationship or when developing
relationships or themes among ideas (ASQ, 2020). RCA should be used to reduce the impact of bias from internal stakeholders and clearly identify issues (Iedema et al., 2008). RCA was conducted using 5 Whys and Fishbone diagram. Gap analysis was done to identify gaps and where focus should be directed to eliminate weaknesses. A gap analysis approach was used to understand the difference between the current object of activity and the desired object (White & Patton, 2002).

- The Study phase studied and analyzed results to determine if the desired results have met the goals. Analysis of data was completed and compared to predictions. The Study phase assessed the implementation of standardization to UAV pilot training. Quantitative and qualitative data gathered from quality tools provided a framework for deciphering the advantages and disadvantages of standardizing UAV flight training for pilots.

- The Act phase applied an action to identified results for reduction in changes that do not contribute to process improvement or increase in additional changes to further improvement (Moen, 2009). The Act phase served to identify process modifications based on observed results to improve UAV flight training.

**Scope and Limitations**

The UAS industry includes drones of all sizes as well as communication equipment that includes satellites orbiting in space. The scope of this study focused on training requirements of military drone operators and civilian pilot contractors to the military that fly the Predator model UAV and why there are inconsistencies between manned and unmanned flight training on the Predator models. The literature search outlined information about flight training in the U.S. CFR requirements are available through February 2020 for both commercial and remote pilot requirements. Military flight training requirements were taken from military websites with the most up-to-date information posted. The study was limited to public documentation of UAV accidents due to human factors published by the military, UAV manufacturers, and universities that have conducted studies. There was few published research studies in the UAV operations field so the material was minimal. This study did not conduct any interviews with UAV manufacturers or military units that fly UAV.
**Definition of Terms**

**Command and Control (C2) Link**: The data link between the UAS and the control station for the purposes of managing the flight. Note: These links are the wireless means of connecting one location to another for the purpose of transmitting or receiving data (Bureau of Engineering, City of Los Angeles, 2017).

**Handover**: The act of passing pilot-in-command responsibilities from one control station or pilot to another (Bureau of Engineering, City of Los Angeles, 2017).

**Remote Pilot**: Responsible for coordinating ground and flight operations including mission planning, execution, and debriefing; safe operation of the aircraft; aircrew resource management; along with customer coordination and coordination with the public (Bureau of Engineering, City of Los Angeles, 2017).

**Remotely Pilot Station**: The component of the remote pilot aircraft station containing the system used to pilot the remotely piloted aircraft (International Civil Aviation Organization [ICAO], 2015).

**Remotely Piloted Aircraft System**: A remotely piloted aircraft, its associated remote pilot stations, the required command and control links, and any other components as specified in the type design (ICAO, 2015). Remotely Piloted Aircraft System (also known as RPAS) is synonymous with UAS.

**Visual Line-of-sight Operation**: An operation in which the remote pilot of RPA observer maintains direct unaided visual contact with the remotely piloted aircraft. When weather conditions are above the minimums prescribed for visual meteorological conditions, remote PICs may fly with visual reference to the UAS and other structures without continuous referral to other visual or locating aids (Bureau of Engineering, City of Los Angeles, 2017).
CHAPTER 2

REVIEW OF LITERATURE

Anything that moves through air responds to aerodynamics. The rules of aerodynamics explain how an airplane can fly. Aerodynamics is the way air moves around an entity and has four forces of flight, which include lift, weight, thrust, and drag. These forces make an object move up and down, and faster or slower. The amount of each force changes how the object moves through the air (May, 2017). The motion of the airplane through the air depends on the relative strength and direction of the forces. If the forces are balanced, the aircraft cruises at a constant velocity. If the forces are unbalanced, the aircraft accelerates in the direction of the largest force (Hall, 2015).

When an aircraft is in straight and level flight, a pilot has minimal pressure on the flight control stick or yoke. When a pilot pulls back (aft) on the flight controls, the aircraft is going to pitch up raising its nose. This motion changes the airflow over the wings and increases lift and therefore drag. If thrust is not applied and the wing’s critical angle of attack is exceeded, the airplane is going to stall. An airplane stall is an aerodynamic condition that occurs when smooth airflow over the airplane’s wings is disrupted, resulting in loss of lift (FAA, 2016). Aircraft stall symptoms are reduced speed, roll to one side, and a sensation that the airplane is falling. Manned pilots practice maneuvering the airplane into a stall configuration to recognize the sight, sound, feel, and how to recover. Recognition of an aircraft stall is just one of the many things that are imperative to flight safety. Flying using sight, sound, and feel is the foundation for learning how to pilot a manned aircraft.
Airplanes have been flying since the beginning of the twentieth century. Orville Wright, who flew the first manned airplane, was lying on his stomach and moved his body to roll the aircraft and pushed or pulled a lever to pitch the aircraft up and down. These basic flight controls progressed to sophisticated flight controls and systems that mimic the future.

The commonality with how aircraft fly is the ability to gain lift. UAV fly with the same principles under the four forces of flight. Over a century later, aerospace technology is so advanced that UAV have been flown using satellites orbiting in outer space. Figure 4 illustrates an airborne Predator providing aerial surveillance that is commanded by an aircrew operating from a Ground Control Station sending commands to a Satellite Data Link System to communicate with the Predator.
Exponential Growth in Unmanned Aerial Vehicles

Drone use has grown exponentially in the last several years due to numerous factors that are pushing its development and growth. A report from the Association for Unmanned Vehicle Systems International and the Danish Technological Institute found that research and innovation are driving increased UAS operations for the academic, civil, commercial, consumer, and military markets. The Global Trends of UAS report analyzed data from Association for Unmanned Vehicle Systems International unmanned systems and robotics database, with findings that 80% of patents associated with UAS technologies had been issued since 2016.
demonstrating the exponential growth of the unmanned systems industry (General Aviation News, 2019).

The Central Intelligence Agency operated an early Predator model called the GNAT 750 over Bosnia and Herzegovina in the mid-1990s, but the program suffered from technical issues (Strickland, 2013). After working to make improvements, the platform was a success and real-time video was viewed from command centers in the United States while the GNAT 750 was flying over Bosnia. The Central Intelligence Agency realized that it would not take long for military analysts, operators, and commanders to direct the asset to provide surveillance of targets of interest located in remote locations. This flight demonstration introduced a partnership with the Department of Defense (DoD), and the GNAT was transitioned into the Defense UAV Program Office. It is fair to say that the Predator’s operational successes—and much of DoD’s dependence on UAV for intelligence today—were outgrowths of the GNAT’s success over Bosnia.

The Unmanned Systems Integrated Roadmap FY 2017-2042 issued in 2018 stated that the DoD has maintained a vision for the continued expansion of unmanned systems into the Joint Force (USAF, USA, U.S. Navy, and U.S. Marines) structure and has identified areas of interest and investment that are going to further expand the potential integration of unmanned systems. The report also states that the DoD envisions unmanned systems seamlessly operating with manned systems to compress the warfighter’s decision-making process while reducing the risk to human life. The foundational areas of interest that are going to accelerate unmanned systems into the future addressed in the Roadmap are as follows:

- Interoperability. Has historically been and continues to be a major thrust in the integration and operation of unmanned systems. Manned and unmanned systems have increasingly synergized their capabilities, focusing on the critical need to use open
and common architectures. A robust interoperable foundation provides the very structure that is going to allow for future advances in warfighting.

- **Autonomy.** Advances in autonomy and robotics have the potential to revolutionize warfighting concepts as a significant force multiplier. Autonomy will increase the efficiency and effectiveness of both manned and unmanned systems, providing a strategic advantage for DoD.

- **Network Security.** Unmanned systems operations ordinarily rely on networked connections and efficient spectrum access. Network vulnerabilities must be addressed to prevent disruption or manipulation.

- **Human-machine Collaboration.** If interoperability lays the foundation, then human-machine collaboration is the ultimate objective. Teaming between human forces and machines will enable revolutionary collaboration where machines will be valued as critical teammates (Fahey & Miller, 2018).

The USAF began flying Predator UAV in the early 2000s after the attacks on September 11 in New York. In 2004, the USAF alone flew five combat air patrols, which translates to twenty Predators flying 24-hour orbits over targets (Everstine, 2018). While the USAF primarily had utilized the Predator MQ-9 Reaper model, the USA hired GA-ASI in 2005 to develop the Predator MQ-1C Gray Eagle, which was more capable for the USA mission. The MQ-1C Gray Eagle has flown 436,840 total hours while maintaining 92% Combat Operational Availability, and since FY 2018 operations have increased with flight hours and deployments (DOD, 2018).

As a sign of how much the military had grown to rely on RPA’s, the Predator and Reaper drones hit two million combat flying hours by 2013 (Losey, 2018). By 2016, the USAF flew 60 combat air patrols which significantly increased the number of flying Predators over targets (Everstine, 2018). GA-ASI—the manufacturer of the Predator UAV—reported in November of 2019 that its Predator-series of RPA, which includes the Predator, Predator B, Gray Eagle, Avenger, and MQ-9B SkyGuardian lines, had surpassed six million flight hours (GA-ASI, 2020).

Predator UAV models range in cost anywhere between $4 million to $16 million per unit. The DoD FY 2020 budget estimates reported flyaway unit cost for a Predator B/MQ-9 Reaper at
$15.9 million (United States Air Force, 2019). The DoD FY 2020 budget mission area category for Aircraft and Related Systems allocated 23% or $57.7 billion of the investment budget request. The funding in this category has provided for advancing technology, procurement of aerospace equipment and systems, modifications to existing aircraft, and procurement of initial spares. Within Aircraft and Related Systems, UAS subgroup requested $3 billion (DOD, 2019).

The exponential growth and use of UAV have benefited service members and the public in multiple ways. First, UAV have provided military commanders with valuable intelligence on targets that would not have been captured if not for UAV aerial surveillance. Forest fires have been located and extinguished before they raged out of control. Hurricane tracking provided movement to emergency services so the public was made aware of evacuation routes and urgency. The illicit activity has been spotted and U.S. Customs and Border Protection agents have secured our borders, protecting millions of Americans. This agency also lets other law enforcement entities “borrow” its drones (Sengupta, 2013). All of these successes have been achieved due to the sensors aboard the UAV—primarily the optical sensor that is known as the eye in the sky.

Federal Aviation Administration (FAA) Oversight

The FAA is the government agency responsible for the safety of civil aviation. The FAA’s major roles include

- regulating civil aviation to promote safety,
- encouraging and developing civil aeronautics, including new aviation technology,
- developing and operating a system of air traffic control and navigation for both civil and military aircraft,
- researching and developing the NAS and civil aeronautics; developing and carrying out programs to control aircraft noise and other environmental effects of civil aviation, and
• regulating U.S. commercial space transportation (FAA, 2019).

The FAA (2018) Strategic Plan for FY 2019-2022, in alignment with the Department of Transportation Strategic Plan, outlined areas of focus based upon the envisioned state of aviation in the next decade. The FAA Strategic Plan forecasted the small UAS model fleet would likely more than double in size over the next five years—from the present 1.1 million units to over 2.4 million units. FAA projects that by 2022 the UAS non-model fleet would likely grow from the current 110,604 registered aircraft to over 450,000. Further examination and research would be needed to forecast the future of large UAS more accurately. The FAA has been developing safety enhancements to reduce risks and enable the safe and secure integration of UAS into the NAS, and their innovation goals are to achieve the following three objectives:

1. Activity 1. UAS Integration Pilot Program. Through the UAS Integration Pilot Program, the FAA will partner with state, local, and tribal governments to undertake projects that will provide the necessary data to inform future rulemaking activities, processes, and procedures.

2. Activity 2. UAS Traffic Management. The FAA, in partnership with National Aeronautics and Space Administration and industry, will work to develop a framework that enables the automation of traffic management for unmanned aircraft.


The FAA has increased oversight as the growth of UAV use is now blending into the National Airspace System (NAS). Small UAV have existing guidelines on flight requirements. However, the FAA has yet to establish guidance on large UAV requirements for operators.

**Flight Requirements**

The FAA requirements to obtain a Remote Pilot Certificate for Commercial Operators flying small scale drones less than 55 pounds went into effect in 2016 (see Table 1). The main
requirements for obtaining a Remote Pilot Certificate are taking a knowledge test and registering the small-scale drone. In order to obtain a manned Private and Commercial Pilot license for a single-engine airplane, the FAA requires more than the requirements for obtaining a Remote Pilot Certificate (see Table 2). Flight training to obtain a commercial pilot license is normally done on an airplane similar in size and operational parameters for a large-scale UAV (see Figure 3).

Requirements for operating large scale UAV in special use airspace is more complicated than operating small scale drones, and FAA oversight is expected to increase as large-scale UAV operations begin outside of restricted airspace and fly in the NAS. Human errors are in the top three reasons why UAV accidents occur (Whitlock, 2014). Operating the UAS has been a challenge since the beginning of the program. The emphasis on pilot training to reduce safety concerns, increase transparency, and focus on how pilots are to operate in the complex UAS environment is needed now more than ever.

Use of Unmanned Aerial Vehicles

Challenges

The crash of one Predator UAV not only costs millions of dollars, but it can cause irreparable damage to the UAS community (Shaw, 2014). The U.S. government has invested a lot of time and money into the UAS program. Even though the use of UAV for combat is to keep humans out of harm’s way, public opinion of UAV use differs. Public opinion is that UAV cannot be trusted; they are an invasion of privacy and civil liberties, are unethical, and are most importantly a safety issue.

The controversial UAS program dates back to the early 2000s and has provoked intense debate for its apparent violation of international humanitarian law and national sovereignty. The
Bureau of Investigative Journalism has reported that up to 2,000 civilians have been killed and over 14,000 confirmed strikes have been completed overseas (Fielding-Smith & Purkiss, 2020). In 2010, the U.S. State Department spoke about the legal justification for the strikes that have included drones, but it was not until two years later that the administration admitted that the drone campaign existed (The Bureau of Investigative Journalism, n.d.). The DoD UAS Roadmap has identified that trust and transparency are key factors for future success. A lack of trust by the warfighters and the wider public is a major roadblock in DoD continued development and use of autonomous unmanned systems (Fahey & Miller, 2018). Establishing trust with the UAS program ensures that human authority remains in the center.

As growth continues, autonomous systems must be transparent and be able to explain decisions and actions, as well as communicate plans concise enough for human-machine teaming (Fahey & Miller, 2018). A memorandum released by the Secretary of Defense in 2018 stated, “The DoD components will report all domestic UAS operations within existing administrative and operational reporting standards” (Mattis, 2018). The memorandum also stated that to ensure accountability and promote transparency in the protection of privacy—and to ensure conformance with law, regulations and guidance related to privacy and civil liberties—the reporting should be done by submitting annual reports by November 1 that summarize UAS domestic operations during the previous fiscal year. Public opinion is not in favor of the reporting requirements and has addressed the issues of not being able to maintain privacy with knowledge before the operations due to only being made aware of operations after the fact. The Washington Post had obtained documents that detailed scores of unreported military UAV that have come crashing down in areas outside of restricted space (Whitlock, 2014). The unreported
crashes have challenged the federal government’s assurance that there has been transparency and that UAV are safe.

A survey of the public knowledge regarding UAS roles, capabilities, and safety was conducted in 2013 by Embry Riddle Aeronautical University. The survey results showed that 95% of the polled individuals were familiar with UAS. Less than half of the polled individuals felt that the acceptable use of UAS in the NAS was for firefighting and weather monitoring. The highest level of concern was for privacy (46%), followed by safety (38%) (Vincenzi et al., 2013).

The DoD failed to earn the public’s trust and recognize that to be transparent they also needed to disclose why failures had occurred. The public addressed trust and privacy violations, but safety concerns remained at the top of the list. The Washington Post’s year-long investigation of drone crashes between 2001 and 2014 found that 400 large scale military drones had crashed in major accidents around the world—in farmer’s fields, on private residences, on runways, highways, and waterways--and have had near mid-air collisions with commercial airplanes. The Post analyzed more than 50,000 pages of accident reports and reported that accidents were caused by mechanical breakdowns, weather, and human error (Whitlock, 2014).

**Human Factors**

In aviation, human factors are devoted to a better understanding of how humans can be most safely and efficiently integrated with the technology (Civil Aviation Safety Authority, 2020). That understanding can then be adapted into the design, training, policies, or procedures in order to help humans perform better. Even with rapid gains in technology, humans are ultimately responsible for ensuring the success and safety of the aviation industry. Humans must continue to be knowledgeable, flexible, dedicated, and efficient while exercising good judgment (Graeber, 2020).
Humans are essential to the everyday operation of UAV. The Predator often operates under autopilot, but most of its functions occur under the control of a pilot, a sensor operator, and a mission intelligence coordinator located in a ground-control station or a mission control center. In this way, the Predator is more “manned” than many other combat aircraft (Connor, 2018). Despite having more operators than a traditional fighter jet the unmanned component in UAS establishes several hurdles for ideal human performance, including loss of sensory cues valuable for flight control, delays in control and communications loops, and difficulty in scanning the visual environment surrounding the vehicle. In most situations, a crew of two or three individuals operates one UAV at a time. There are times when a signal operator is in control of multiple UAV synchronously, which can introduce degradation of human performance.

Operational challenges exist when exponential growth does not include preparation and training. Operational challenges include

- piloting the aircraft,
- collision avoidance-capabilities (limited due to primarily used only for the mission),
- C2 issues-jamming, frequency loss caused by weather or banking the airplane can cause loss of signal,
- crew task saturation-monitoring electrical systems and radios, multiple screens of data to review, and
- susceptibility to weather and moisture-electric servos and is not an all-weather aircraft (U.S. Government Accountability Office [GAO], 2013).
**Cultural Challenges**

The author of this thesis has over 20 years of experience working as a military service member in the aviation field, flying UAV, and working for government regulatory agencies. The author has logged over 3,000 hours working with multiple military UAV units during deployed operations and has flown with officers, enlisted, government, and civilian operators.

Cultural challenges exist in unmanned pilot training. The UAV operators for the USAF include officers and enlisted members. Some officers have experience flying manned aircraft prior to flying UAV. On the other hand, the USA has very few officers trained to fly them. The USA UAV operators are enlisted members, and the majority of them have no prior flight experience. With the growth rate of UAV, the USAF and USA began training non-pilot operators. The cross of officer ranks with enlisted ranks, pilots, and non-pilots have created friction over privileges and status since UAV operators can essentially perform the same duties but do not have the same training.

The U.S. military operates a large number of UAV. Although the number includes more small-scale UAV than large-scale UAV, the capabilities of large-scale UAV make them a primary choice for operations that require one asset that can fulfill multiple roles. The demand for UAV has grown, but military branches have had a challenging time recruiting, training, and retaining UAV pilots. Prescreening and assessments during the initial pilot selection phase has failed to select the most appropriate pilots to fly UAV; therefore, attrition rates for UAV pilots during flight screening is three times that of manned pilots (Hoagland, 2013).

A Brookings Institution study reported that USAF drone pilots only made up 8.5% of total USAF pilots, but daily mission requirements had grown at a faster pace than how quickly
UAV pilots can be trained. This study noted that there were critical gaps identified in the USAF’s ability to recruit and train UAV pilots (Hoagland, 2013).

**Training Challenges**

Challenges exist not only with operating UAS but way before UAV are even airborne. The UAV are unmanned aircraft, but humans are very much a part of UAV operations. Humans design, manufacture, create software programs, maintain, and pilot the UAV. Each of these elements contributes to the success or demise of each flight. The one element that is always present during operations is the pilot. A UAV pilot’s responsibilities include flight planning, preflight tests, and inspections, engine starts, taxiing, take off, airborne operations, mission planning and execution, navigation, monitoring electrical and mechanical systems, radio communications, preparation for landing, after landing checks, and post-flight duties. Each one of these duties happens every time a UAV is scheduled to fly. Each one of these duties takes an immense amount of technical understanding and skill to complete the task successfully.

U.S. Code Title 10, DoD Instructions, and DoD Directives identifies the categories of performers authorized to conduct the authorized operations of UAV as:

- uniformed military personnel
- government service civilians
- contracted support (contractor)

Enlisted service members make up the backbone of the services. Eligibility for enlistment begins at seventeen years of age, and a high school diploma is desirable but not mandatory. Officers must be U.S. citizens and have a baccalaureate degree. A DoD civilian is typically defined as a federally appointed employee by United States Code Title 5, Government Organization, and Employees. These individuals are appointed into the civil service and are
“engaged in the performance of a Federal function under authority of law or an executive act” (Norton, 2016). U.S. Code Title 5 defines a DoD contractor as an independent individual and/or company that has been contracted by or on behalf of DoD to accomplish a DoD-related function.

Each category of authorized performers must have the required training and qualifications to operate UAV. Challenges and inconsistencies exist when authorized performers do not have standardized training and have only met a portion of the requirements when they begin operating UAV. When a pilot’s knowledge is limited, he or she may misinterpret the objective data. For example, limited knowledge and understanding concerning a Flight Management System may result, fatally, in inappropriate action. Flight Management Systems include navigation, aircraft performance, aircraft operations that display data during preflight, engine start, landing, and shut-down and therefore are crucial to understanding what the onboard computer is displaying (Flight Safety Foundation, 2020). About 80% of flight mistakes involve human factors that if not detected would lead to accidents (FAA, 2006). There are many challenges in unmanned flying, but applying resources and attention toward reducing human errors decreases the possibility of a human error causing an accident. Table 3 lists common causes of human factor errors generally referred to as the Dirty Dozen.
Table 3

**Human Error Conditions That Can Act as Precursors to Accidents**

<table>
<thead>
<tr>
<th>Human Factor Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of knowledge</td>
<td>Shortage of the training, information, and/or ability to successfully perform</td>
</tr>
<tr>
<td>Complacency</td>
<td>Overconfidence from repeated experience performing a task</td>
</tr>
<tr>
<td>Lack of Communication</td>
<td>Failure to transmit, receive, or provide enough information to complete a task. Never assume anything.</td>
</tr>
<tr>
<td>Distraction</td>
<td>Anything that draws your attention away from the task at hand.</td>
</tr>
<tr>
<td>Lack of Awareness</td>
<td>Failure to recognize a situation, understand what it is, and predict the possible results</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Physical or mental exhaustion threatening work performance</td>
</tr>
<tr>
<td>Norms</td>
<td>Expected, yet unwritten, rules of behavior</td>
</tr>
<tr>
<td>Pressure</td>
<td>Real or perceived forces demanding high-level job performance.</td>
</tr>
<tr>
<td>Lack of Resources</td>
<td>Not having enough people, equipment, documentation, time, parts, etc., to complete a task.</td>
</tr>
<tr>
<td>Stress</td>
<td>A physical, chemical, or emotional factor that causes physical or mental tension</td>
</tr>
<tr>
<td>Lack of Teamwork</td>
<td>Failure to work together to complete a shared goal.</td>
</tr>
<tr>
<td>Lack of Assertiveness</td>
<td>Failure to speak up or document concerns about instructions, orders, or the actions of others.</td>
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In April 2014, the U.S. Government Accountability Office (GAO) found multiple deficiencies in the administration of UAV pilot career fields by the USAF. The deficiencies
noted were inadequate crew-to-aircraft ratio, the lack of a strategy to recruit and retain UAV pilots to meet the needs of the USAF, and the lack of opportunities for advanced training and education. The GAO reported to Congressional committees in May 2015 that the USAF and USA drone pilots were often unable to complete their training due to demanding operational schedules. “Pilots in all of the seven focus groups GAO conducted with USAF UAS pilots stated that they could not conduct training in units because their units had shortages of UAS pilots” (Gettinger, 2015).

In 2016, the Senate Armed Services Committee stated the following: “The committee is concerned that the remotely piloted aircraft career field is under severe strain because of increased combatant commander requirements, consistently insufficient USAF personnel policy actions to improve manning levels, and is compounded by the USAF losing more remotely piloted aircraft pilots than it is training” (Gettinger, 2015). In 2017, the GAO conducted a study to review USAF and USA human capital planning for pilot workforces and noted the USAF had quadrupled its requirements for UAS pilots but faced challenges meeting the requirements due to pilot shortages (GAO, 2017).

This study also reported that Army UAS units had a higher mishap rate than any other aircraft, and Army officials stated that training shortfalls had contributed to the mishaps. The GAO recommended that the USAF address tailoring requirements to meet pilot shortages and that the Army revise strategy to address training shortfalls. The study concluded that “The Air Force and the Army have not fully applied four of the five key principles for effective strategic human capital planning for managing pilots of unmanned aerial systems (UAS) that are important for resolving the Air Force’s pilot shortages and the Army’s training shortfalls” (Farrell et al., 2017).
The most recent report released by the GAO in June of 2020 states that the USAF does not have enough pilots to meet staffing targets for UAS, does not track overall progress in accessing and retaining enough UAS operators, and does not have a comprehensive metric to predict whether it is on track to meet the 2024 policy goals (Farrell, 2020). The foundation for successful flight programs begins with proper training. The complexity of flying unmanned aircraft is increased; therefore, UAV operators need to have standardized training and ample time to complete the requirements before being placed in an operational environment.

**Opportunities**

Pilots are kept out of harm’s way. When UAV are flown over hostile areas engaging in combat sorties, that is one less mission a manned aircraft with a pilot on-board is doing—keeping the pilot safe. The benefits of the military use of UAV include operations from multiple locations, long flight time durations, and fuel efficiency. The UAV can also be used as multiple service platforms to carry weapons, conduct video surveillance, and intelligence collection. Opportunities exist for UAV on multiple scales. In addition to UAV being used for locating forest fires, observing weather patterns, and geological surveys, law enforcement, and border protection, UAV are being looked at in the medical, real estate, and transportation industries.

The use of large-scale UAV is moving into commercial sectors, and new capabilities are being developed to ensure the demand is being met. Commercial industries are looking to use UAV for delivering medicine, critical packages, and equipment for front line emergency services. A recent success story of the progress of the UAV in the civil sector began with the United Parcel Service Flight Forward (USPFF) Drone Airline being the first to be awarded a full CFR, Title 14, Chapter 1, Subchapter F, Part 135-Air Carrier and Operator certification by the
FAA. United Parcel Service Flight Forward and Wingcopter are working to develop a new versatile drone fleet (United Parcel Service, 2020).

**Potential Risks and Harm of UAV**

**Risks**

Predator UAV have completed multiple missions and have flown millions of hours, but the risk of flying them still exists. After years of experience flying the Predator, models have been uncontrollable, have malfunctioned, and have even disappeared. In 2009, an armed Predator Reaper had to be shot down because it was flying on the loose after the pilot had lost control of it. In 2010, an armed Predator cratered because the pilot did not realize it was being flown upside down. In another instance, a Predator crashed in 2010 because the pilot did not realize the wrong button was pushed, which sent the Predator into a spin (Whitlock, 2014).

The USAF sustained 271 mishaps involving UAV between 2011 and 2017 (Insinna, 2018). Many of these accidents have occurred overseas but Predator accidents have also occurred in the United States. Drones have crashed into schoolyards, plummeted into the ocean, and crashed onshore igniting wildfires.

In 2014, *The Washington Post* article “When Drones Fall from the Sky” reported on safety issues, but those same safety issues are still present with operating UAV. Limited ability to detect and avoid trouble, pilot error, mechanical defects, and unreliable C2 are safety issues that still exist. Increased risks are present, as inconsistencies and nonstandard training exist among UAV pilots and operators resulting in human factors errors that cause accidents. Military drone pilots consist of enlisted service members and officers. A frequent point raised when determining the distinction between UAS programs is the role of enlisted members vs. officers. Risks exist when there are multiple categories of operators with varying levels of training.
**USAF UAV Training Requirements**

The USAF (2020) Air Education and Training Command is responsible for training USAF aircrews. The USAF enlisted members flying RPA attend a six-week three-skill-level awarding course to learn the following:

- communication
- sensor operator duties
- RPA crew duties

Pilots, who are officers and selected to fly RPA, can be one of the following:

- Temporarily reassigned manned-aircraft pilots.
- Manned-aircraft pilots and other USAF aviation officers who have converted to this career permanently.
- Graduates of manned-aircraft pilot training on their first assignment.
- Pilots who specialize in flying UAS with limited manned-aircraft experience.

USAF RPA flight training for officers is conducted in two phases:

- Phase 1. UAS pilots who specialize in flying a UAS attend five months of training called undergraduate UAS training. This training consists of three courses:
  - First, these pilots learn to fly a small, manned aircraft for 39 hours.
  - Second, they use a simulator to learn to fly a manned aircraft using instruments.
  - Third, they learn about the fundamentals of flying a UAS in a classroom setting. USAF UAS pilots who the USAF re-assigns from its manned-aircraft pilot ranks do not attend this first phase of training because they received flight training as manned aircraft pilots.

- Phase 2. All UAS pilots attend a four-month course at a formal training unit to learn to fly one of the USAF’s three UAS platforms. Most active duty USAF pilots attend the formal training unit at Holloman USAF Base to learn to fly the USAF’s MQ-1 Predator or MQ-9 Reaper (GAO, 2015).
Army UAV Training Requirements

USA trains enlisted service members as Unmanned Aircraft Systems operators to fly UAV and the enlisted members receive no manned aircraft flight training. Army Unmanned Aircraft Systems operator training is conducted in two phases:

- **Phase 1.** Eight-week common core course for all UAS pilots. During this phase, USA is responsible for teaching its pilots the fundamentals of aerodynamics, flight safety, and navigation.

- **Phase 2.** Operators fly one of the Army’s three UAS. This training lasts between 12 and 25 weeks depending on the UAS that is the focus of the course. During this phase, the USA teaches its pilots to launch and recover a UAS, conduct reconnaissance and surveillance, and participate in a field training exercise. Also, all USA UAS pilots are trained as sensor operators (GAO, 2015).

DoD Civilian UAV Flight Training Requirements

DoD civilians appointed to civil service that operate UAV are employed by agencies like the U.S. Customs and Border Protection, U.S. Forest Service, Federal Bureau of Investigation, and as previously discussed, Central Intelligence Agency. Civilians flying UAV for these agencies have common training and flight experience requirements, and DoD civilians typically must meet the requirements listed in Table 2, be a U.S. citizen, have logged at least 1,500 flight hours, 250 PIC hours, 75 hours night time flying, 75 hours instrument flying time, and have or can obtain a FAA First Class or Second Class Medical Certificate (Customs and Border Protection, 2020).

Civilian Contractor Flight Training Requirements

Civilian contractors to the military are also utilized to supplement military units and operate UAV for assorted reasons. Costs and availability are two reasons why the military uses civilian contractors. GA-ASI is a leader in UAV manufacturing, and they also train and employ a large number of civilian Predator pilots. Requirements for employment with GA-ASI to work as
contracted support flying UAV must meet the requirements listed in Table 2 and have a current instrument rating, have logged at least 700 flight hours, 500 PIC hours, and 1,000 UAV hours; have obtained an FAA Second Class Medical certificate; and are able to obtain a DoD security clearance.

The utilization of multiple types of authorized operators enables the military to conduct more operations in more areas supporting numerous programs. However, not all UAV pilots are trained with the same standards, nor do they all meet the same requirements. Military units are under pressure to perform and meet operational and intelligence community needs which often leads to training being cut short or waivers being issued to reduce or cut training requirements.

A study conducted in 2015 by the GAO reported that the USAF and USA faced challenges ensuring their pilots have completed the required training. The report found that “Army unit status reports do not require UAS pilot training information, and as a result, the Army does not know the full extent to which pilots have been trained and are therefore ready to be deployed” (GAO, 2015). The report also found the following: “Air Force training records from a non-generalizable sample of seven UAS units showed that, on average, 35% of the pilots in these units completed the training for all of their required missions.” Pilots in all of the seven focus groups GAO conducted with Air Force UAS pilots stated that “they could not conduct training in units because their units had shortages of UAS pilots” (GAO, 2015).

USA risks that its UAS pilots may not be receiving the highest quality of training needed to prepare them to successfully perform UAS missions. The USA UAS units’ mishap rate has been higher than the rate for other aircraft, and training shortfalls have contributed to the mishaps (GAO, 2015). The USAF shortage of staffed training command is a primary reason the USAF has a shortage of UAV pilots, which puts a strain on current qualified pilots and flights at higher
risk. The ramifications with training shortages do not end with the shortage of pilots. The risks include human factors errors (see Table 3) that lead to accidents, mid-air collisions with other UAV, or more detrimental incidents with manned aircraft.

**Harm**

The ICAO has identified human error as one of the top safety risks to aviation safety. As human factors are considered a primary contributing factor in incidents and accidents, it again offers the possibility of adding crucial improvements to aviation safety. Human error has evolved from being considered the cause of a symptom of system failure (ICAO, 2014). Normal human errors like slips and lapses are most likely to happen to more experienced people and can happen anytime, especially during simple and frequently performed tasks. Normal human errors are not going to be fixed with more training but with more cross checks, checklists, and error-tolerant systems. Normal human errors like mistakes happen when less experienced people work on complex systems and on tasks that are rarely performed. Training, standardization, supervision, clear documentation, and guidance on decisions are ways to overcome mistakes.

Regardless of how workforce costs are calculated, using an enlisted military member always costs less than using an officer. Similarly, when assessing the officer corps, warrant officers always cost less than utilizing the “traditional” officers. The greatest workforce cost savings were available using government civilians to conduct non-kinetic UAS operations (Norton, 2016). The harm in using enlisted service members over officers is lack of training and experience, which introduces more risk and system failure. Cost savings may occur when enlisted members fill more of the operator positions, but the cost of crashing one large scale UAV costs millions of dollars and possible loss of life. Cost savings may also occur when utilizing contracted civilians, but harm is introduced when the military relies on contracted
civilians, who are at-will employees and may decide to abandon forward-deployed operations at any time, leaving military units without UAV support on which they rely.

The FAA Safety Team’s mission statement is “Lower the Nation’s aviation accident rate by conveying safety principles and practices through training, outreach, and education; while establishing partnerships and encouraging the continual growth of a positive safety culture within the aviation community” (FAA, 2020b). The FAA has multiple safety programs, and the aviation industry and the FAA now share a goal to reduce risks in the NAS by 50% from 2010 to 2025 (National Highway Traffic Safety Administration, 2016). Key FAA safety programs include Safety Management System, Compliance Philosophy, Voluntary Reporting Programs, Commercial Aviation Safety Team, and Aviation Safety Information Analysis and Sharing Program.

Two primary FAA safety programs are the Safety Management System and Compliance Philosophy. The FAA Safety Management System includes procedures, best practices, and policies that uses a top-down organization-wide approach to monitoring safety risk and assuring the effectiveness of safety controls. The system is structured so that organizations internal to the FAA and external aviation industry organizations manage safety. The Safety Management System promotes a safety culture to improve the overall performance of the organization. It uses four key components—safety policy, safety risk management, safety assurance, and safety promotion. The FAA’s Compliance Philosophy was developed to enhance the FAA’s ability to find safety problems before they result in an incident or accident, use the best tools to fix those problems, and then monitor the situation to ensure that no new problems develop. This approach recognizes that most operators comply with the rules and voluntarily use the Safety Management
System to identify hazards. They then assess the risks from those hazards and put measures in place to mitigate these risks (FAA, 2019).

Despite having a robust safety program, the FAA still must investigate incidents and accidents. On May 20, 2020, a USAF pilot flying a manned T-38 Talon airplane had a close call with a drone flying at 1500 feet. This near mid-air collision violated multiple FAA regulations requiring drones to fly below 400 feet; they also are restricted from flying near a military installation or near an airport without FAA approval (Wheaton, 2020). Incidents like this harm the aviation community. Drone operators violate rules, and investigations cannot happen until after the fact. The FAA promotes voluntary compliance but also has enforcement tools such as warning notices, letters of correction, and civil penalties. The problem with enforcing drone regulations is it is not effective if the operator for enforcing the regulations cannot be located.

The FAA has established a policy for small scale UAV operating in the NAS, but violations occur daily. The FAA receives more than 100 drone violation reports each month (FAA, 2020c). Table 4 is an example of drone violations being reported to law enforcement.
### FAA UAS Sightings Report

<table>
<thead>
<tr>
<th>Date of Sighting</th>
<th>State</th>
<th>City</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/1/20</td>
<td>New York</td>
<td>New York</td>
<td>Preliminary information from FAA operations: New York, NY/UAS Incident/1037E/Laguardia ATC traffic advised Airbus A321, enroute Palm Beach International to Laguardia, reported a UAS while southwest bound at 900 Feet to northeast Laguardia. Evasive action taken. NYPD notified.</td>
</tr>
<tr>
<td>3/1/20</td>
<td>New York</td>
<td>New York</td>
<td>Follow up information from FAA Operations: New York, NY/UAS Incident/1008E/Bombardier Glex, Farnborough, United Kingdom (EGLF) to John F Kennedy International, after action investigation discovered language barrier interfered with detailed reporting. UAS was below the aircraft and made no contact.</td>
</tr>
<tr>
<td>3/1/20</td>
<td>Florida</td>
<td>Miami</td>
<td>Preliminary information from FAA operations: Miami, FL/UAS incident/1047E/Miami Terminal Radar Approach Control advised B763, John F Kennedy International to Miami International, reported a black and gold UAS while southbound at 3,000 feet. No evasive action taken. Miami Dade Police Department notified.</td>
</tr>
<tr>
<td>3/1/20</td>
<td>Florida</td>
<td>Orlando</td>
<td>Preliminary information from FAA operations: Orlando, FL/UAS incident/1230E/Orlando Air Traffic Control Tower advised Piper PA32, to Orlando International, reported a UAS while east northeast bound at 500 Feet, west southwest of Orlando. No evasive action taken. Orange County Sheriff notified.</td>
</tr>
<tr>
<td>3/1/20</td>
<td>California</td>
<td>Concord</td>
<td>Preliminary information from FAA operations: Concord, CA/UAS incident/1535P/Concord Air Traffic Control Tower advised Cessna T206, observed a purple quadcopter UAS while northbound at 2,000 feet 6 S Concord. No evasive action taken. Law enforcement notification not reported.</td>
</tr>
</tbody>
</table>

Automated systems are used to track airplanes to ensure safety and compliance. Gaps in best practices with the NAS exist with drones not being required to transmit location data for the aircraft or the pilot. There are concerns regarding operators being required to transmit their location, but the larger concern is with drones not being required to transmit position data that includes altitude, flight path, and emergency code. Drones can operate in any type of airspace without leaving an identifiable trace (Moore, 2020). Without being able to identify compliance or to enforce regulations, safety cannot be ensured.

**Summary**

Exponential growth in the UAS industry has created opportunities for military and civilian users to stay out of harm’s way. UAV growth has included the technological advancement and development of multiple Predator variants—logging more than six million flight hours, expanding military use, and branching out into civilian airspace and use. The FAA has implemented regulations and pilot requirements for small scale drones but has yet to implement regulations and pilot requirements for large scale UAV. Accident investigations have revealed that human factors are among the top causes or contributing factors for accidents. Safety concerns have identified inconsistencies and no standardization with UAV pilot training for the four authorized operators and the lack of manned flight training or experience before flying UAV.
CHAPTER 3

METHODOLOGY

This study used Deming’s PDSA theoretical framework to identify gaps in flight training programs to propose standardized training. The focus of this research sought to emphasize the need for standardized training that would allow organizations to utilize knowledge sharing among all UAV operators to reduce accidents and improve safety. The author of this thesis was the lead researcher, and management team members were experts from regulatory agencies, a UAV manufacturer, and manned and unmanned flight operations with more than 35 years combined experience. Table 5 displays data sources and responsibility matrix for the literature review. Management team members were qualified and certified subject matter experts with diverse knowledge in safety, flight operations, quality assurance, and federal regulations compliance and enforcement. The cross-functional management team collected data for analysis and the data was populated into the quality tools.

Table 5

Responsibility Matrix

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>Safety Manager</th>
<th>Compliance Manager</th>
<th>Chief Pilot</th>
<th>Training Manager</th>
<th>Quality Manager</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAV Use</td>
<td>C</td>
<td>R</td>
<td>A</td>
<td>A</td>
<td>I</td>
<td>Responsible</td>
</tr>
<tr>
<td>Safety Management</td>
<td>A</td>
<td>C</td>
<td>R</td>
<td>R</td>
<td>I</td>
<td>Consulted</td>
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<tr>
<td>Risk Management</td>
<td>C</td>
<td>A</td>
<td>R</td>
<td>I</td>
<td>R</td>
<td>Accountable</td>
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<tr>
<td>Quality Management</td>
<td>R</td>
<td>I</td>
<td>I</td>
<td>C</td>
<td>A</td>
<td>Informed</td>
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</table>

Note. Created by the author of this thesis.
The Model for Improvement was utilized to map a sequence for investigation where quality tools were used to build the progression of the study. A set of quality tools were used to establish knowledge sharing, awareness, and education on the importance of standardized training to the individual operator, military operators, and civilian entities looking to operate UAV.

**Plan Phase of PDSA**

The *Plan* phase gathered information, established an understanding of the current situation, and identified problems. This PDSA phase applied several quality methods to evaluate the need for the proposed standardized training for all UAV operators. The benefits of standardized training were central to the objectives of the proposed knowledge-sharing program. Several quality tools were identified as the most beneficial for supporting the application of the Model for Improvement. They included SWOT, FMEA, affinity diagram, RCA (5 Whys and Fishbone diagram), and gap analysis.

**SWOT Analysis**

The SWOT analysis was used for the initial step in the quality planning process to organize gathered information regarding the use of UAV. Key issues were identified and focused on for the overall planning strategy. The internal environment and risk factors (S=strengths and W=weaknesses) and external environment and risk factors (O=opportunities and T=threats) were categorized using SWOT analysis, based on occurrence and severity, addressed the root causes of failures in UAV operations.

*Strengths*—internal environment factors—were listed in the upper-left corner of the quadrant. These factors identified the benefits of using UAV. *Weaknesses*—internal environment risk factors—were listed in the upper-right corner of the quadrant. These factors identified
shortcomings of using UAV. Weaknesses indicated issues present in the current system.

*Opportunities*—external environment factors—were listed in the lower-left corner of the quadrant. These factors are probable future developments and improvements in UAV use.

*Threats*—external environment risk factors—were listed in the lower-right corner of the quadrant. These factors were elements that could pose a problem or cause trouble for UAV use.

Table 6 displays proposed SWOT analysis quadrants.

**Table 6**

*Proposed Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis Template*

<table>
<thead>
<tr>
<th>Internal Factors</th>
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<tbody>
<tr>
<td><strong>Strengths</strong></td>
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<tr>
<td><strong>Weaknesses</strong></td>
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</table>

<table>
<thead>
<tr>
<th>External Factors</th>
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<tbody>
<tr>
<td><strong>Opportunities</strong></td>
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<tr>
<td><strong>Threats</strong></td>
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*Note.* Created by the author of this thesis.
FMEA Risk Assessment

FMEA is a step-by-step approach for identifying failures in a process, product, or service. FMEA captures general knowledge and actions about the risks of failure for use in continuous improvement. The sequence used for FMEA application are as follows:

1. identify items for analysis
2. identify ways failure can happen (failure modes)
3. identify consequences (failure effect)
4. determine the severity (S) of effect and assign a rating (Scale 1–none to 10–Injury or Death to crew or total destruction of property)
5. determine causes of failure, estimate the probability of failure occurring, and determine occurrence (O) rating (Scale–remote to 10–extremely high)
6. identify current controls in place to keep the cause from happening and determine detection (D) rating (Scale 1–almost certain to 10–absolutely uncertain)
7. calculate risk priority number (RPN) by multiplying severity by occurrence by detection (S x O x D) and rank failures in the order they should be addressed

Table 7 illustrates an example of the FMEA summary table associated with the “dirty dozen” human factor errors (see Table 3) that can act as precursors to aircraft accidents.
Table 7

*Proposed Failure Modes Effects Analysis (FMEA) for Human Factor Errors*

<table>
<thead>
<tr>
<th>Item</th>
<th>Human Factor</th>
<th>Failure Modes</th>
<th>Effects of Failure</th>
<th>Severity (S)</th>
<th>Major Causes of Failure</th>
<th>Occur (O)</th>
<th>Current Controls</th>
<th>Detect (D)</th>
<th>RPN (S<em>O</em>D)</th>
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*Note.* Created by the author of this thesis.

Utilizing FMEA can assist in analyzing failures within human factors and with the proposal to redesign UAV flight training to meet improvement goals.

**Affinity Diagram**

Affinity diagrams are used to organize data and consolidate information related to problems. Data is grouped according to affinity or similarity. The process to complete an affinity diagram for this study was grouping human factors into affinities to identify relationships. Figure 5 displays an affinity diagram used to identify relationships.
Figure 5

Proposed Affinity Diagram

<table>
<thead>
<tr>
<th>Training</th>
<th>Environment</th>
<th>Mechanical</th>
<th>Uncontrollable</th>
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<tbody>
<tr>
<td>HF</td>
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Note. Created by the author of this thesis.

Root Cause Analysis

A RCA helps organizations uncover causes of problems or failures a program needs to address in order to make continuous improvements. This analysis was conducted to determine whether current UAV pilot training contained weaknesses and risks to future operations. The problems were identified, and data revealed causes that contributed to the problem or were the cause of the problem. Questions used to identify causal problems were:

1. What sequence of events led to the problem?
2. What conditions allowed the problem to occur?
3. What problems coincided with the main problem and may have contributed to it?
Asking “Why?” a problem that exists leads to causal factors and eventually reveals the root cause or core issue.

**5 Whys to Uncover Root Cause**

Asking 5 Whys methodically digs into the root cause of a problem. This questioning process searches for the relationship of causes to the problem. The 5 Whys tool defines the problem by asking why five times to find the root cause to eliminate the problem or prevent reoccurrence. Table 8 illustrates the use of the 5 Whys quality tool for identifying problem statement causes and effects.

**Table 8**

*Proposed 5 Whys Analysis*

<table>
<thead>
<tr>
<th>Define the Problem</th>
<th>Problem Statement</th>
</tr>
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<tbody>
<tr>
<td>Why?</td>
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<td>Why?</td>
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<td>Why?</td>
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</table>

*Note.* Created by the author of this thesis.

**Fishbone Diagram**

The Fishbone diagram is a quality tool for determining causes leading to an effect. The cause-and-effect diagram shows potential causes for an effect or problem. Causes of the problem are organized in categories—known as affinities—to assist with determining the impact of
different causes for each affinity. The affinities are displayed as ribs of the fish, and the effect or problem is at the head where the affinities (causes) all point to the head (effect or problem) like a Fishbone. Figure 6 demonstrates the cause-and-effect organization with affinities of similar root causes.

**Figure 6**

*Proposed Fishbone Diagram to Analyze Causes of Problems and Corresponding Effects*

Note. Created by the author of this thesis.

**Gap Analysis**

A gap analysis is planned to learn the current-state process and its deficiencies. In this thesis, a gap analysis was used to compare actual performance with what is expected with UAV flight training programs. This method provided a way to identify substandard processes,
practices, and skills and to recommend steps for improvement. The gap analysis was critical in completing the following steps:

1. Identify the area to be analyzed and identify what needs to be accomplished.
2. Establish what the future or ideal state would be.
3. Analyze the current state and compare it with the ideal state.
4. Review gaps and make recommendations to bridge the gaps.

Table 9 illustrated the gap analysis tool to identify where gaps were in existing flight training programs and where organizations could focus on performance improvements.

Table 9

*Proposed Gap Analysis Tool to Identify Current Processes and Deficiencies*

<table>
<thead>
<tr>
<th>UAV Operator</th>
<th>Best Practice</th>
<th>How Best Practice Differs</th>
<th>Gaps Between Existing Practice and Best Practice</th>
</tr>
</thead>
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*Note. Created by the author of this thesis.*

The planning phase provided a collection of data and past performance to fully understand the behavior of the current process. By creating a visual perspective of the current inputs, process, and performance output, additional gaps and opportunities could be identified to specify additional control measures required to mitigate risk. In summary, the Plan phase asked what we were going to do.
Do Phase of PDSA

The *Do* phase consisted of documenting observations, problems, outcomes, and unexpected findings. The Do phase of PDSA implemented the research plan and populated data into the selected quality tools. This phase ensured that the identified Plan phase tasks and research plan data was collected and understood. Literature review data was integrated into the development of the SWOT analysis and provided direction to the study. Completion of the SWOT quadrants revealed internal and external components that would have the potential to impact the successful future use of UAV. The Fishbone diagram was completed after the 5 Whys table revealed cause-and-effect relationships to develop true root causes. A gap analysis was conducted to assess differences in performance between the four categories of authorized performers of UAV to determine shortcomings that needed to be overcome. In summary, the Do phase asked when and how things were done.

Study Phase of PDSA

The *Study* phase described the measured results, determined if a change was expected, and looked at how it compared to predictions. This phase assessed the data of inconsistencies in UAV flight training programs and was analyzed to determine risk and impact to create a proposal. The results from the FMEA, affinity diagram, SWOT analysis, 5 Whys, Fishbone diagram, and gap analysis could encourage further explanation by determining the relationship between potential root causes and current performance. This phase summarized what was learned and looked for successes and failures. Adjustments were made to set the proposal up for favorable results. In summary, the Study phase evaluated results and outcome impacts.
Act Phase of PDSA

The Act phase described what modifications to the plan were made that were required in order to reach a continuous improvement proposal for the standardization of UAV flight training. Specifically, process modifications were identified to promote change in current training that would result in quality improvements and increased safety. If results indicated that further modifications were necessary in order to carry out plan goals, the determination to restart a new cycle was made. In summary, the Act phase asked what changes would be made based on the findings.
CHAPTER 4

RESULTS AND DISCUSSION

Deming’s PDSA theoretical framework served as the foundation for this study in order to develop a proposed continuous evaluation system for the improvement, standardization, and implementation of best practices in UAV flight training programs. This study used quality tools to obtain actionable data and information for assessing the current state of UAV use in order to support organizations in reducing accidents and improving safety. This study analyzed drone pilots’ adherence to manned aircraft training standards for obtaining a pilot certificate prior to flying drones. Data analysis resulted in categorizing the information provided within two sets of information that included the following:

1. understanding current UAV flight training standards and practices
2. identifying risk process reduction improvements pertaining to UAV flight training

The research team began with the SWOT and FMEA tools to identify current uses of UAV and problem and opportunity areas associated with them. The SWOT tool provided general qualitative details and was used to design a strategic understanding of the study. The FMEA tool was used to identify risks and quantified causes and effects using an RPN calculation from risks associated with severity, detection, and occurrence frequency. An affinity diagram was developed next to find the relationship between the identified risks. RCA was performed with the 5 Whys questioning process and Fishbone diagram to uncover root causes and affinity groupings linking causes with effects. Along with RCA, a gap analysis was conducted in order to bridge the Fishbone diagram and establish where gaps existed by comparing the four categories of performers’ current training with best practices.
SWOT Analysis of Current UAV Use

SWOT analysis was first conducted to understand the internal and external factors of the current use of UAV and to detect risk areas. Areas of this analysis were populated with ideas generated during Kaizen events with the management team members, as shown in Table 5. Factors evaluated were focused on exponential growth, current practices, and risk. Each of the factors was prioritized with the most crucial factors listed in priority sequence.

The strengths associated with UAV use reinforced the successful growth, application, and operation of UAV in the present time. Identified strengths could be leveraged to improve the future development of UAV flight training.

The following *Strengths* were identified in the SWOT analysis:

1. Humans are not at risk when operations are conducted in hostile environments.
2. UAV can be operated from multiple locations. Collaborative teams work together to provide input.
3. UAV are more fuel-efficient and can fly for longer flight time durations. Aircrews are familiar with long missions.
4. Multiple services platforms (fire weapons, video surveillance, and intelligence collection) provide support to teams in need of various functions in order to complete missions.
5. The desire and demand for UAV has drastically increased.

The weaknesses associated with UAV use illustrate that its use is still at high risk even with technological advancement and exponential growth, and 100% reliance on automated machines cannot happen. Humans are required for every step of operations.

The following *Weaknesses* were identified in the SWOT analysis:

1. Human factor errors are the primary reason for UAV accidents due to the pilot being remote, which degrades the efficiency and safety of the UAV.
2. Pilots are task saturated with too many operational demands during a flight that affect performance, increase safety issues, and degrade UAV performance reducing efficiency.

3. Collision avoidance capability decreases without a pilot on board creating airborne safety issues.

4. UAV are susceptible to losing communication links between ground station, satellites, and aircraft making the UAV uncontrollable.

5. UAV are susceptible to weather and moisture making it difficult to rely on them in any airspace.

The opportunities associated with the use of UAV reiterated the multifunctional benefits and the ability to keep humans safe. Several external factors that were identified could provide opportunities to promote education which will increase safety.

The following *Opportunities* were identified in the SWOT analysis:

1. UAV use expanded into law enforcement, emergency services, fire prevention, and border patrol.

2. UAV use assisting with research, conservation, wildlife monitoring.

3. Weather and storm tracking capabilities that can alert agencies to send out notifications to the public.

4. UAV growth merging into commercial applications to assist with critical supply delivery.

5. Research in test and evaluations of larger airspace.

The threats associated with the use of UAV provided insight into the consequences of an inadequate emphasis on pilot training. The current state of authorized operators being trained under various requirements created a divided UAV community and a lack of confidence in operators flying in joint airspace.

The following *threats* were identified in the SWOT analysis:

1. Human factor errors cause avoidable accidents.
2. Safety concerns with inconsistencies and lack of standardization in pilot training. The four authorized operators all have various requirements for being accepted into training programs and what is required to complete training prior to operating UAV.

3. Waivers of training requirements for military pilots to reduce training due to demands for pilots in the field.

4. The lack of consistent pilot training expectations for all UAV pilot groups.

5. Accelerated integration of UAV into the National Airspace System without proper integration is a risk.

Table 10 identifies the internal and external factors organized into the four quadrants of the SWOT matrix.
Table 10

SWOT Analysis for Unmanned Aerial Vehicle Use

<table>
<thead>
<tr>
<th>Internal Factors</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strengths</strong></td>
<td><strong>Weaknesses</strong></td>
</tr>
<tr>
<td>1. Pilots are kept out of harm’s way.</td>
<td>1. Human factor (remote) errors can degrade efficiency or safety of the UAV.</td>
</tr>
<tr>
<td>2. Can be operated from multiple locations.</td>
<td>2. Too many demands on pilot can degrade UAV performance and effectiveness.</td>
</tr>
<tr>
<td>3. Longer flight time duration and fuel efficient in operations.</td>
<td>3. Air safety—collision avoidance capability decreased without pilot onboard.</td>
</tr>
<tr>
<td>4. Increased demand and desired use.</td>
<td>4. Issues with C2 of UAV Operations—jamming and frequency loss.</td>
</tr>
<tr>
<td>5. Can serve as multiple services platforms—fire weapons, video surveillance, intelligence collection.</td>
<td>5. Susceptible to weather and moisture therefore pilot must always monitor exterior environment.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>External Factors</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opportunities</strong></td>
<td><strong>Threats</strong></td>
</tr>
<tr>
<td>1. Can be used by police, emergency services support, and border protection for aerial surveillance.</td>
<td>1. Human factor errors cause avoidable accidents.</td>
</tr>
<tr>
<td>2. Conservation, wildlife, and fire prevention can be conducted simultaneously.</td>
<td>2. Safety concerns with inconsistencies and lack of standardization in pilot training.</td>
</tr>
<tr>
<td>3. Can provide long endurance flights to predict weather and storm tracking (hurricanes).</td>
<td>3. Waivers of training requirements issued to military pilots to reduce training due to demands for pilots in the field.</td>
</tr>
<tr>
<td>4. Researchers can conduct test and evaluations in larger airspace for real world data.</td>
<td>4. Lack of consistent pilot training expectations for all UAV pilot groups.</td>
</tr>
<tr>
<td>5. Growth into commercial applications.</td>
<td>5. Accelerated integration of UAV into the National Airspace System without proper integration is a risk.</td>
</tr>
</tbody>
</table>

*Note.* Created by the author of this thesis.
SWOT was a valuable tool for developing a qualitative method and perspective about actionable information. This tool provided adequate structure to be large in scope in categorizing a wide range of factors. Summaries from each category provided adequate actionable information to begin developing a plan for solutions. The SWOT analysis identified human factors as a re-occurring risk in two areas—the Weaknesses and Threats categories.

**Failure Modes Effects Analysis Risk Assessment**

FMEA was used to understand risk and failure modes related to the Weaknesses and Threats quadrants from the SWOT analysis. Analyzing the SWOT Weaknesses and Threats categories provided an opportunity to identify internal and external risk factors associated with UAV use. SWOT revealed human factors as a re-occurring risk and the FMEA matrix was completed using the 12 most common human factors that contribute to accidents (see Table 3). The brainstorming event defined risk as harm to people and or property and assigned ratings and values in three risk categories. The risk categories were:

- **S**=Severity: the impact the failure would have
- **O**=Occurrence: the probability that the failure will occur
- **D**=Detection: the probability that the failure will be avoided

A value between one and 10 was used to determine the rank of each risk category in order to calculate the RPN. Table 11 explains the risk ranking description for each of the risk categories.
### Table 11

**FMEA Risk Category Rankings for Human Factor Contributors**

<table>
<thead>
<tr>
<th>Score</th>
<th>Severity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Catastrophic</td>
<td>Extreme risk with injury or death to people or total destruction of property</td>
</tr>
<tr>
<td>8-9</td>
<td>Critical</td>
<td>Hazardous risk with some warning to people or significant property damage</td>
</tr>
<tr>
<td>6-7</td>
<td>Serious</td>
<td>Loss of some functionality from crew and property.</td>
</tr>
<tr>
<td>3-5</td>
<td>Minor</td>
<td>Gradual crew performance degradation. Property operated at reduced performance.</td>
</tr>
<tr>
<td>1-2</td>
<td>Negligible</td>
<td>Risk is a minor nuisance to the crew. Property sustains little to no damage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Score</th>
<th>Occurrence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Inevitable</td>
<td>Will happen during a flight.</td>
</tr>
<tr>
<td>8-9</td>
<td>Likely</td>
<td>One occurrence every three to four days.</td>
</tr>
<tr>
<td>6-7</td>
<td>Occasional</td>
<td>One occurrence per week.</td>
</tr>
<tr>
<td>3-5</td>
<td>Possible</td>
<td>One occurrence per month.</td>
</tr>
<tr>
<td>1-2</td>
<td>Improbable</td>
<td>Unlikely to happen during a flight.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Score</th>
<th>Detectability</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Non-Detectable</td>
<td>Human Factor condition will not be detected, no current control.</td>
</tr>
<tr>
<td>8-9</td>
<td>Remote</td>
<td>Remote chance current control will detect human factor condition.</td>
</tr>
<tr>
<td>6-7</td>
<td>Low</td>
<td>Current controls have a poor chance of detecting human factor condition.</td>
</tr>
<tr>
<td>3-5</td>
<td>Moderate</td>
<td>Current controls may detect human factor condition.</td>
</tr>
<tr>
<td>1-2</td>
<td>Highly Detectable</td>
<td>Current controls will detect Human factor condition.</td>
</tr>
</tbody>
</table>

*Note.* Created by the author of this thesis.

Risk was quantified by calculating the RPN from multiplying $S \times O \times D = RPN$. The RPN values with the highest values represented the highest risk. Table 12 shows the populated FMEA summary table associated with human factors errors.
Table 12

*FMEA Summary of Human Factors that Contribute to UAV Accidents*

<table>
<thead>
<tr>
<th>Human Factor</th>
<th>Failure Mode</th>
<th>Effects of Failure</th>
<th>(S)</th>
<th>Major Causes of Failure</th>
<th>(O)</th>
<th>Current Controls</th>
<th>(D)</th>
<th>RPN (S<em>O</em>D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Communication</td>
<td>Message Lost</td>
<td>10</td>
<td></td>
<td>Failure to transmit or receive</td>
<td>7</td>
<td>Use of checklists and logbooks</td>
<td>9</td>
<td>630</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>Inability to perform</td>
<td>10</td>
<td></td>
<td>Shortage of training</td>
<td>9</td>
<td>Continuing professional development</td>
<td>7</td>
<td>630</td>
</tr>
<tr>
<td>Stress</td>
<td>Inability to perform</td>
<td>10</td>
<td></td>
<td>Physical, chemical, emotional factor that can cause physical or mental tension</td>
<td>7</td>
<td>Crew Resource Management Training</td>
<td>6</td>
<td>420</td>
</tr>
<tr>
<td>Lack of Teamwork</td>
<td>No Crew environment</td>
<td>9</td>
<td></td>
<td>Failure to work together</td>
<td>6</td>
<td>Defined Roles and Goals</td>
<td>7</td>
<td>378</td>
</tr>
<tr>
<td>Lack of Resources</td>
<td>Task saturation</td>
<td>7</td>
<td></td>
<td>Not enough people, equipment, or time to complete tasks</td>
<td>7</td>
<td>Workforce Development</td>
<td>7</td>
<td>343</td>
</tr>
<tr>
<td>Distraction</td>
<td>Incomplete work</td>
<td>9</td>
<td></td>
<td>Attention drawn away from completing a task</td>
<td>6</td>
<td>Use checklists, repeat if incomplete</td>
<td>6</td>
<td>324</td>
</tr>
<tr>
<td>Pressure</td>
<td>Inability to perform</td>
<td>9</td>
<td></td>
<td>Demanding job performance</td>
<td>8</td>
<td>Crew Resource Management Training</td>
<td>4</td>
<td>288</td>
</tr>
<tr>
<td>Complacency</td>
<td>Incomplete work</td>
<td>9</td>
<td></td>
<td>Overconfidence</td>
<td>7</td>
<td>Follow written instructions, cross checking</td>
<td>4</td>
<td>252</td>
</tr>
<tr>
<td>Norms</td>
<td>Not following procedures</td>
<td>9</td>
<td></td>
<td>Expected, unwritten rules</td>
<td>7</td>
<td>Follow rules and procedures</td>
<td>4</td>
<td>252</td>
</tr>
<tr>
<td>Lack of Awareness</td>
<td>Incomplete work</td>
<td>10</td>
<td></td>
<td>Failure to recognize a situation</td>
<td>5</td>
<td>Crew Resource Management Training</td>
<td>5</td>
<td>250</td>
</tr>
<tr>
<td>Lack of Assertiveness</td>
<td>Critical tasks go missed</td>
<td>10</td>
<td></td>
<td>Failure to speak up</td>
<td>9</td>
<td>Crew Resource Management Training</td>
<td>2</td>
<td>180</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Inability to perform</td>
<td>10</td>
<td></td>
<td>Physical or Mental exhaustion</td>
<td>8</td>
<td>Required Rest Periods</td>
<td>2</td>
<td>160</td>
</tr>
</tbody>
</table>

*Note.* Created by the author of this thesis.
FMEA Results

The associated impact of the different risks and failures as outlined in the FMEA matrix created opportunities to develop risk-based improvement efforts. The computed RPN values were prioritized from high to low. The highest RPN values were lack of communication and lack of knowledge. Risks arose when there was a reduction or elimination of communication, resulting in failure to send messages, which caused messages to be lost or not sent. Lack of communication often stemmed from lack of knowledge, as the message sender was unaware communication was required and that a message needed to be sent or received. Lack of knowledge risks arose when there was a shortage of training resulting in the inability to perform. Improving communication skills and increased training were some suggestions for reducing or eliminating shortfalls.

Affinity Diagram

Ideas from the brainstorming event populated the affinity diagram to establish human factors relationships. The question the brainstorming event focused on was “How can we reduce human factor errors?” Lack of communication and lack of knowledge were the problems identified with the highest RPN scores. Figure 7 displays natural relationships for human factors and their associated category.
Affinity Diagram Results

The two natural relationships identified for lack of communication and lack of knowledge were training and cultural factors. Further research was recommended to prioritize addressing training in the areas of complacency and lack of resources and cultural factors in the areas of lack of assertiveness, lack of teamwork, and norms.

Root Cause Analysis: 5 Whys and Fishbone Diagram

A Kaizen event was used to stimulate ideas about the most crucial factor listed in the SWOT threat category: Human factor errors cause avoidable accidents. The 5 Whys tool was used to explore the relationship between root cause and identified problem in detail. Table 13
illustrates the 5 Whys table to better understand the relationship between the root cause of why human factor errors cause avoidable accidents and the identified problem.

**Table 13**

*Questions Used in the 5 Whys Analysis to Create the Fishbone Diagram*

<table>
<thead>
<tr>
<th>Define the Problem</th>
<th>Human factor errors cause avoidable accidents. UAV Crashed into Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why?</td>
<td>Why did the UAV fly into terrain? UAV was flying on the wrong heading.</td>
</tr>
<tr>
<td>Why?</td>
<td>Why was the UAV flying on the wrong heading? The pilot was unaware of the location of the UAV and was not communicating with air traffic coordination.</td>
</tr>
<tr>
<td>Why?</td>
<td>Why was the pilot unaware of the location of the UAV and not communicating with air traffic coordination? Pilot used wrong maps and didn’t follow terrain avoidance procedures.</td>
</tr>
<tr>
<td>Why?</td>
<td>Why didn’t the pilot follow terrain avoidance procedures? The pilot was not trained to fly around terrain and was unaware of communication procedures.</td>
</tr>
<tr>
<td>Why?</td>
<td>Why wasn’t the pilot trained to fly around terrain? The pilot received inadequate training.</td>
</tr>
</tbody>
</table>

*Note. Created by the author of this thesis.*

From the 5 Whys method, two root causes were identified and outlined to ensure a resolution of the problem caused by human factors causing avoidable accidents. The conclusion of the 5 Whys analysis were as follows:
- RPN root causes (lack of communication and lack of training) with the effects (messages lost and inability to perform) are commonly linked together when a problem occurs.

- Standardized training is required to ensure UAV operators are all receiving adequate training to perform their job functions in any airspace.

The 5 Whys analysis, along with the SWOT and FMEA analyses, provided information to identify specific individual causes and group affinities related to inadequate training. Figure 8 shows the Fishbone diagram, which indicates the underlying causes of the effect that if a UAV operator receives inadequate training, avoidable accidents are going to occur.

**Figure 8**

*Fishbone Diagram Showing Root Causes and Affinities for Inadequate Pilot Training*
Note. Created by the author of this thesis.

The contributing causes that identified the primary reasons for inadequate training revealed many variables associated with the problem. The main theme suggested that multiple organizations were responsible for ensuring that adequate training was administered to students.

**RCA Results**

The 5 Whys tool was used to better define root causes. Inadequate training was identified as a root cause for avoidable accidents caused by human factor errors. The Fishbone diagram revealed that organizations needed to work together to ensure pilots received the training required to fly UAV in a safe manner and in any airborne condition. The results of RCA provided true root causes to support a proposal for standardized pilot training for all UAV authorized operators.

**Gap Analysis: Best Practices**

A gap analysis table was created to establish where gaps existed by comparing the main components of the FAA commercial pilot license requirements to the four categories of performers authorized to operate UAV under identified current training requirements. Although FAA guidelines were not required for military operators, the comparison would allow UAV operators to improve unmanned flight training requirements and align with manned flight training best practices. Although there are four categories of performers, the gap analysis was conducted using eight groups to establish a true representation of all UAV operators. The groups identified were as follows:

- Group 1. USAF manned-aircraft pilots temporarily reassigned.
- Group 2. USAF manned-aircraft pilots and other USAF aviation officers who have converted to UAV.
- Group 3. USAF pilots who have graduated from manned-aircraft pilot training and are on first assignment.
● Group 4. USAF UAV pilot with limited manned-aircraft pilot training.

● Group 5. USAF enlisted operators.

● Group 6. Army UAV operators.

● Group 7. DoD civilian operators.

● Group 8. Civilian contractor operators.

Table 14 displays information from the gap analysis table.
<table>
<thead>
<tr>
<th>Best Practices</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Group 7</th>
<th>Group 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hold a private pilot license or military equivalent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demonstrate aeronautical knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experience flying technically advanced airplanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight proficiency-takeoffs, landings, go-arounds, performance maneuvers, ground reference maneuvers, slow flight, stalls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250 hours manned aircraft time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 flight hours as pilot in command</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operate aircraft by relying solely on instruments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating in multiple use airspace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Legend: Orange identifies group does not meet best practices. Yellow identifies group meets some of the best practices. Green identifies group meets best practices. Created by the author of this thesis.
**Gap Analysis Results**

The results of the gap analysis revealed gaps and confirmed existing strengths and opportunities within the current UAV pilot training programs. All groups were identified to have sufficient experience flying technically advanced aircraft and have proficient knowledge to fly using instruments with no reference to visual indicators. UAV operators fly sophisticated airplanes but cannot look outside of the aircraft other than using the video camera fixed on the nose of the aircraft. The following gaps were identified:

- Group 3 has a basic level of experience and knowledge flying manned and unmanned airplanes.
- Groups four, five, and six have a significant lack of, or no training flying manned airplanes.
- Substandard processes, practices, and skills that should be required by all operators.
- No standardized training for UAV operators.

Manned flight training establishes a foundation for developing piloting skills and applying practices pertaining to aeronautical knowledge that should be required by all pilots prior to flying UAV.

**Summary of Findings**

Quality tools were employed in this thesis to assess UAV use and the threats associated with operating them. Each quality tool served the purpose of generating reliable qualitative and quantitative data for creating a study proposal aimed at improving pilot training for UAV operators. The SWOT analysis revealed human factors as a re-occurring risk in weaknesses and threats categories. A FMEA was conducted using human factors, and the analysis revealed the highest RPN values were lack of communication and lack of training. The affinity diagram displayed natural relationships for lack of training, which fell under the training affinity, and lack
of communication, which fell under the cultural factors affinity. These relationships could be studied to uncover other human factors that might pose a problem when a lack of training or lack of communication exists. RCA revealed inadequate training as a root cause of human factors that contributed to avoidable accidents. A Fishbone diagram revealed that federal regulation requirements, manpower issues, and educational barriers from lack of funding, lack of time, or lack of resources could lead to inadequate training. The research management team worked as a cross-functional team with collaboration between members that encouraged working together to identify well-rounded inputs and outputs. Humans-in-the-loop was a common factor that was found in each phase of research and was carried through each quality tool.

**Proposal for Standardized Training**

Although adoption of best practices in UAV flight training has not been fully embraced by organizations that operate UAV, there are improvement opportunities for establishing a standardized training program. This would help the UAV industry establish itself as an equal asset to manned aircraft operations. The proposal explored opportunities to reduce risks in the existing flight training programs by looking at short-term changes and explored implementing long-term changes to align with manned aircraft best practices. The proposals were generated from the information that was gathered and analyzed. Proposals focused on relevant information that was analyzed using the PDSA framework, which would ensure continuous improvement of the UAV flight training program.

**Short-term Proposal**

Quality tools have discovered internal risks in current flight training programs. A short-term proposal is based on identified internal weaknesses from SWOT, FMEA, and RCA quality tools. This short-term proposal to improve current flight training requirements emphasizes safety
first and then increased quality of instruction given to pilots. The short-term proposal for organizations to improve safety and quality of instruction includes:

- Eliminate the issuance of waivers to reduce training requirements.
- Increase the amount of instructors to administer training.
- Ensure all students receive required simulator training, flight training, and classroom instruction.
- Increase the amount of crewmembers to reduce amount of demands on one crew.
- Increase the use of checklists, logbooks, and frequent reporting periods to ensure communication does not go missed.
- Increase professional development to reduce the lack of knowledge and inability to perform.
- Incorporate training related to cultural factors to address human factor errors that have a natural relationship with the lack of communication. Increase training in human factor errors that stem from lack of training in complacency and lack of resources.
- Incorporate new training requirements to include private pilot license requirements, or a military equivalent, to establish a foundation with manned training requirements.
- Add risk activities training to ensure successful implementation into flight training programs.

**Long-term Proposal**

Quality tools discovered external risks in current flight training programs. A long-term proposal is based on identified weaknesses and threats from SWOT analysis and groups that do not meet best practices identified in the gap analysis tools. This proposal has been created to incorporate best practices from the manned aircraft industry into current UAV flight training programs. Suggested long-term implementation proposals for organizations to adapt best practices are as follows:

- Federal regulation requiring all UAV operators obtain a commercial pilot license, or military equivalent, for large scale UAV to operate in all airspace.
• Federal budget allotments to improve flight training to include manned aircraft training prior to attending unmanned flight training.

• Allocation of resources for UAV operators to train in manned aircraft.

• Standardized requirements for all UAV operators to include growth in civilian commercial sectors.

Combining short-term and long-term proposals would construct a roadmap for process improvement. Slight adjustments can be made using the PDSA framework to ensure that updates are incorporated, and a strategic approach is achieved within each PDSA cycle. Organizations that successfully adopt the short-term and long-term proposals will improve safety and reduce accidents so that UAV operators will be able to perform as a cohesive group within the manned aviation community.
CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The fascinating advancement of the aviation industry over the last century has broken barriers, allowing it to go above and beyond, and it is still on the rise. Technological advancements have included commercial travel to international locations within the same day, space exploration, and protection of our citizens in times of war. Amateur RC airplanes propelled the use of drones into sophisticated, smart flying machines. The rise of UAV use was to keep humans safe and out of combat zones, but the use of UAV has expanded into the civilian sector at an alarming rate (e.g., expanding more rapidly than regulatory agencies can manage).

The FAA oversees aviation safety and is responsible for regulating operations in the NAS. The FAA has implemented manned aircraft requirements for multiple categories and classes of aircraft, including training requirements. Yet, regulations have not been implemented for large-scale UAV. Many large-scale UAV are comparable in size to some classes of manned aircraft but are not looked at as equivalent. Unfortunately, UAV use has risks and gaps in the emerging industry (e.g., military use merging into the civilian sector) that are not particular to one location or group.

Operating UAV is unique and challenging. Categories of performers authorized to operate UAV include military units, DoD civilians, and civilian contractors. The current acceptable state of individual entities establishing training requirements and training their own
operators has attributed to exponential growth. This has put a strain on safety in the NAS due to UAV accidents primarily caused by human factors errors.

Human factor issues—specifically human errors—contribute to more aircraft incidents and accidents than any other single factor. Inconsistencies exist in training standards between the categories of performers authorized to operate large-scale UAV, which is resulting in inadequate training to UAV pilots.

Amidst limited regulatory guidance over the industry, this study aimed to identify and address issues within current UAV pilot training. This study has demonstrated the importance of establishing standardization in UAV flight training for all operators and a solid foundation through manned flight training prior to flying UAV. The assessment of current UAV pilot training demonstrated the importance of PDSA as a framework to apply quality tools for managing flight training in a limited regulation environment.

Conclusions

The purpose of this study was to establish a comprehensive approach for the analysis of internal and external risk factors of UAV use and flight training requirements using Deming’s PDSA theoretical framework. This study involved the use of quality tools such as SWOT, FMEA, affinity diagrams, and RCA in sequence to be able to propose standardized training for UAV operators. A SWOT analysis identified strengths and opportunities for supporting the safe use of UAV and operations extending into the civilian sector along with weaknesses and threats that could compromise the safety of UAV. The FMEA identified and quantified risks associated with internal weaknesses and external threats uncovered in the SWOT analysis. Focusing on internal weaknesses helped establish a plan for removing risk with a short-term plan. Focusing on external threats helped establish a plan for removing risks with a long-term plan. The highest
failure mode RPN values from the FMEA were then assessed using the 5 Whys technique to understand root causes of the failure modes. A Fishbone diagram identified the effect of pilots receiving inadequate training. The causes identified in association with this effect (problem) included the primary affinities of \textit{training environment, regulation, manpower, and education}.

Data analysis revealed opportunities to display information in effective short-term and long-term proposals that focused on reducing risk, improving safety, and standardizing flight training for UAV operators. Evaluating and studying the consequences of failures and risks provided a systematic framework for prioritizing which UAV operators should receive manned flight training and standardization first.

\textbf{Recommendations}

The use of UAV is growing at an exponential rate as public interest in this technology has significantly increased. The increase in demand and the cross over into civilian airspace has posed many questions regarding risk due to limited regulatory oversight, non-standardized training, and limited resources to improve training. This study investigated a wide range of issues regarding the current use of UAV and how unmanned pilots are trained. Furthermore, identification of risks and process improvements were explored in the context of using Deming’s continuous learning and improvement framework to evaluate existing gaps and identify unmet needs in order to design and implement best practices for unmanned pilot training programs.

Recommendations are presented for organizations to standardize unmanned pilot training programs that align training expectations so that \textit{all UAV pilot groups} meet the same training requirements (e.g., both public and private sectors). The advantages of the proposed manned flight training standardization program prior to operating UAV is that it reduces risks and improves safety. The proposed training program serves to mitigate human errors as a principle
cause of risks and lack of safety. Organizations must take drastic measures to improve the safe use of UAV in all airspace and must align safety management, risk management, and quality management practices to invoke consistent standardized UAV pilot training to improve safety for pilots as well as the general population. This study recommends that the UAV community collaborate with the manned aviation community and adopt a problem-solution approach to implement a standardized UAV training model.
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