# INTEGRATION OF UNMANNED AERIAL SYSTEMS INTO THE US NATIONAL AIRSPACE SYSTEM; THE RELATIONSHIP BETWEEN SAFETY RECORD AND CONCERNS

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Abstract: The purpose of this study was to discover if a relationship existed between the most common safety concerns and the most common UAS accidents with regards to the integration of the unmanned aerial system (UAS) into the National Airspace System (NAS). The study used a Mixed Method approach to find the most common causes of UAS accidents over a five-year period, the level of safety concerns and common concerns from UAS pilots and sensor operators. The quantitative data was derived from the Air Force, Navy and Army Safety Offices, while the qualitative data was derived from an online questionnaire and follow-up interviews of US Air Force UAS pilots and sensor operators. Review and observation of the data consisting of data comparison, was conducted to discover if there were any relationship between safety concerns and safety accidents. Comparison between the most common accidents during the three phases of flight and the level of safety concerns that each research subject had for accidents to occur during those phases of flight was completed.

UAS flight profiles were categorized into takeoff, cruise and landing and the most common accidents (pilot error, engine failure, loss of control and lost link), were divided into the respective phase of flight. Engine failure proved to be the most common cause for accidents while most accidents occurred during the cruise phase of flight. The USAF pilots and sensor operators' showed a slight level of concern on a scale of 1-5 with regards to accidents occurring with a UAS. Comparison showed there was a positive relationship between the number of accidents during takeoff and landing phases, which had the lowest occurrences, and a slight level of concern of accidents occurring during these phases. There was a negative relationship between the number of accidents during cruise, the highest occurrences of accidents, and the level of concern which was slight. The observed number of near midair and midair collisions were low, which showed a positive relationship with the level of concern, observed as a slight concern. These findings can be attributed to the follow-up interview in which the pilots and sensor operators did not believe safety was the biggest concern when integrating the UAS into the NAS.

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CHAPTER I

## Introduction

Integration of Unmanned Aerial Systems Into the US National Airspace System; The Relationship Between Safety Record and Concerns

By passing the Modernization and Reform Act 2012, Congress created potential safety hazards with additional aircraft in an already congested national airspace. The introduction of the UAS into the public aviation system is a new venture that may have negative effects to the NAS, as well as a negative public perception. There are unknowns pertaining to effects on safety regarding midair collision avoidance, terrain avoidance and lost link incidents. The US Government Accountability Office (GAO) has addressed some of the safety concerns:

1. The inability for UAS to detect, sense, and avoid other aircraft and airborne objects in a manner similar to “see and avoid” by a pilot in a manned aircraft,

2. Vulnerabilities in the command and control of UAS operations,

3. Lack of technological and operational standards needed to guide the safe and consistent performance of UAS, and

4. Lack of final regulations to accelerate the safe integration of UAS into the national airspace (GAO, 2012, p. 1).

There have been several recent studies based on UAS features and the ability for the aircraft to meet safety standards. One such study conducted by Cuerno-Rejado, C., & Martínez-Val, R. (2011) addressed UAS civil airworthiness and the regulatory efforts from manufacturers' standpoint and how they compare to the operational procedures. Another study conducted by Casarosa, C., Galatolo, R., Mengali, G., & Quarta, A. (2004), before the new legislation passed, suggested that, "The lack of airworthiness and certification criteria for the employment of UAS vehicles in the civilian field has caused an uncontrolled proliferation of projects and the construction of a number of UAS prototypes which differ in dimension, weight, flight characteristics and payload carriage (Casarosa, 2004)." Even though these studies address safety, there has not been research conducted on the safety concerns with comparison to the accident record.

## Purpose of the Study

The purpose of this study was to investigate the most common unmanned aerial system (UAS) accidents from 2009-2014 and determine a relationship between actual UAS accidents and safety concerns regarding their integration into the National Airspace System (NAS) existed. The research survey and interview questions created by the researcher explored the most common safety concerns and why they were a specific concern of US Air Force (USAF) UAS pilots and sensor operators.

A convergent mixed methods research approach consisting of a collection of quantitative and qualitative data was utilized in this study to address the safety concerns associated with the integration of the unmanned aerial system into the National Airspace System. The reason for collecting both quantitative and qualitative data was to validate the safety concerns of the integration of the UAS into the NAS from a statistical standpoint from a small UAS expert group.

## Significance of the Study

Anyone who has flown or will fly within the borders of the US will find this study significant because a "first of its kind within the borders of a country" process will be introduced into the aviation environment in 2015. Today, unmanned aerial systems fly for military, government and research use around the world; but a new ideal will be in effect in September 2015 when any individual with the proper accreditation can fly a UAS within the US airspace. As a result, the US public has raised many questions and concerns with the new regulations:

- Are UASs safe to fly in the same airspace as aircraft carrying passengers?
- Do they have failsafe systems?
- Will they be able to avert midair collisions or return safely to an airport if their connectivity to the pilot is lost?

The answers to these questions alone are significant enough reasons to conduct the study.

## Research Objective and Questions

The research methodology was designed with the intent of producing qualitative and quantitative results to answer the following research objective and following questions:

Research Objective: Based on the most common UAS accidents causes and US Air Force UAS instructor and evaluator pilots and sensor operators, is there a relationship between safety concerns and safety issues?

Research Questions:

1. What safety feature prevents UAS midair collisions?
2. How many times has this safety feature prevented midair collisions?
3. What safety feature prevents accidents during lost link events?
4. How many lost link incidents have occurred ending with accidents?
5. How many lost link incidents have occurred ending without accidents?
6. What are the most common UAS accidents within the last five years?
7. Have UAS meeting airworthiness requirements been involved in more accidents than UAS not meeting airworthiness requirements?

Additionally, because there is not a significant sample size utilized for this research, the following inferential research questions were utilized to support the qualitative research method of the mixed method study:

1. How do current (Independent Variable 'IV') and proposed (IV) safety features integrated into a UAS prevent the most common accident (Dependent Variable 'DV') occurrences?

2. Does UAS pilot training (IV) reduce the number of UAS accidents (DV)?

## Research Approach

The quantitative approach was conducted to find the most common causes of UAS incidents, accidents and mishaps between June 2009 and June 2014 through the use of online databases. To receive expert opinions on safety, the qualitative research method consisted of a research survey and interview questions created for US Air Force UAS instructors and evaluator pilots and sensor operators. The information gathered from the qualitative approach was compared to the quantitative findings to see if a relationship between the safety concerns and safety records existed and if the concerns were valid, as well as assessing answers to the posed research objective and questions.

## Assumptions

The researcher makes the following assumptions regarding this study:

1. The accident reports provided by the US Air Force, Army and Navy safety offices are an accurate and reliable source of accident data and information.

2. The answers and information provided by the USAF UAS pilots and sensor operators were truthful and non-biased.

## Limitations

The researcher acknowledges the following limitations associated with this study:

The challenge with conducting this research study is conducting the qualitative portion of the study on a large enough sample of the US military to garner significant results. This challenge is due to time allotted for the study, funding and the ability to reach out to a large enough sample population given military regulations and restrictions.

## Terminology

Accident: occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and until such time as all such persons have disembarked, and in which any person suffers death or serious injury or in which the aircraft receives substantial damage. (Aviation-terms, 2015).

Airworthiness: (of an aircraft) meeting established standards for safe flight; equipped and maintained in condition to fly. (Dictionary.com, 2015).

Certificate of Authorization (COA): authorization issued by the Air Traffic Organization to a public operator for a specific UA activity; a Federal Aviation Administration grant of approval for a specific flight operation. (FAA, 2014).

Civil Aircraft: means aircraft other than public aircraft. "Class": (1) as used with respect to the certification, ratings, privileges, and limitations of airmen, means a classification of aircraft within a category having similar operating characteristics. Examples include: single engine; multiengine; land; water; gyroplane; helicopter; airship; and free balloon; and (2) As used with respect to the certification of aircraft, means a broad grouping of aircraft having similar characteristics of propulsion, flight, or landing. Examples include: airplane; rotorcraft; glider; balloon; landplane; and seaplane. (Aviation-terms, 2015).

Civil Unmanned Aircraft System: an unmanned aircraft system that meets the qualifications and conditions required for operation of a civil aircraft.

Collision: the act of colliding; a coming violently into contact; crash. (Dictionary.com, 2015).

Cruise (CR): any level flight segment after arrival at initial cruise altitude until the start of descent to the destination. (Phase of Flight Definition, 2013, p. 5)

Federal Aviation Administration (FAA): the division of the Department of Transportation that inspects and rates civilian aircraft and pilots, enforces the rules of air safety, and installs and maintains air-navigation and traffic-control facilities. (Dictionary.com, 2015).

Federal Aviation Administration Modernization and Reform Act 2012: authorized appropriations to the FAA from Fiscal Year 2012 through Fiscal Year 2015. The legislation also seeks to improve aviation safety and capacity of the national airspace system, provide a framework for integrating new technology safely into our airspace, provide a stable funding system, and advance the implementation of the Next Generation Air Transportation System (NextGen). (FAA, 2014).

Engine Failure (E): engine in an aircraft unexpectedly stops producing thrust due to a malfunction other than fuel exhaustion. (Wikipedia, 2014).

Incident: an occurrence other than an accident associated with the operation of an aircraft, which affects or could affect the safety of operations. (Aviation-terms, 2015).

Landing (L): from approach until after touchdown until aircraft exits the landing runway or comes to a stop, whichever occurs first. (Phase of Flight Definition, 2013, p. 7)

Loss of Control (CT): a descent during any airborne phase in which the aircraft does not sustain controlled flight; includes any portion of the flight after intentional or unintentional termination of flight, such as following system/component malfunction or failure or loss of control in flight. (Phase of Flight Definition, 2013, p. 7)

Lost Link (LL): loss of command and control link between control station and aircraft.

Public Unmanned Aircraft System: an unmanned aircraft system that meets the qualifications and conditions required for operation of a public aircraft.

National Airspace System (NAS): is the airspace, navigation facilities and airports of the United States along with their associated information, services, rules, regulations, policies, procedures, personnel and equipment. (Wikipedia, 2015).

Other (O): phase of flight is not discernible from the information available, or, accident cause did not fall into one of the four major categories of the study.

Pilot Error (PE): the action or decision of the pilot that, if not caught or corrected, could contribute to the occurrence of an accident or incident, including inaction or indecision. (Human Factors & Pilot error, 2014).

See and Avoid: when weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

Sense and Avoid: the capability of an unmanned aircraft to remain a safe distance from and to avoid collisions with other airborne aircraft.
Takeoff (T/O): from the application of takeoff power, through rotation and to an altitude of 35 feet above runway elevation. For unmanned aircraft systems, includes launching from any system or by any method, including systems such as a catapult.

Terrain: The contour of the earth or man-made obstacles such as buildings, utility poles, walls or vehicles.

UAS Pilot (Officer): individual pilots that operate the UAS (and crews) who are physically located in control centers often thousands of miles from the aircraft. These officers have completed the same undergraduate flight training as other pilot specialties.

UAS Sensor Operator (Enlisted): as members of the crew on UAVs, UAS Sensor Operators employ airborne sensors and sophisticated video imagery equipment to monitor airborne, maritime and ground objects.

Unmanned Aerial System (UAS): unmanned aircraft, control station and the command and control link used to connect the two.

Unmanned Aerial Vehicle (UAV): a powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload.

CHAPTER II

## Review of Literature

For years the UAS has been used in the War on Terror and the capabilities have not gone unnoticed. The Federal Aviation Administration Modernization and Reform Act 2012 was passed in part to help aid US law enforcement agencies and the Department of Homeland Security increase their capabilities in protecting US citizens domestically (FAA, 2012, p. 1). By passing the legislation, the clock has started for federal agencies such as the FAA to solve the issues that derive from introducing an unmanned aircraft into the public airways (FAA, 2012). This review of literature provides an overview of the research as it pertains to: (1) UAS flight operations in the NAS, (2) UAS safety features, (3) UAS types and airworthiness requirements, (4) FAA Certification of Authorization process, and (5) UAS flight training requirements.

This research study focused on the incidents and accidents that have occurred for military UAS operations within the US and overseas flight environments. The researcher utilized military UAS incidents and accidents due to availability of information and statistics showing the Department of Defense (DoD) as the largest operator and requester for operations within the NAS daily. As UAS operations increase within the NAS, it is possible that the rules, regulations and procedures for future operations may come from what has been learned from UAS operations during the War on Terror.

## FAA Modernization and Reform Act of 2012

The FAA Modernization and Reform Act of 2012 was enacted in February 2012 and according to the FAA was legislated to "improve aviation safety and capacity of the national airspace system, provide a framework for integrating new technology safely, provide a stable funding system, and advance the implementation of the Next Generation Air Transportation System (NextGen)," (FAA, 2014). Though the reform act covers all these legislative programs, the one that stood out to the public was "integrating new technology safely;" this new technology being the UAS. In Title III-Safety, Subtitle B of the Modernization and Reform Act, the integration of the Unmanned Aircraft System is discussed; it is this section that has brought the most attention to the 2012 Reform Act.

Within Subtitle B, UAS, the legislation spells out how the UAS will be integrated into the NAS, special rules and safety studies. The Act also states that there will be a Roadmap for the integration of the UAS into NAS "no later than 1 year after the date of enactment," (Modernization Act, p. 64, 2012); this Roadmap was drafted in 2013 and is referenced later in this study.

When reviewing the Act, some of the biggest challenges faced by the FAA and integrating the UAS into the NAS include, "ensuring that any civil unmanned aircraft system includes a sense and avoid capability; establishing standards and requirements for the operator and pilot of a civil unmanned aircraft system; best methods necessary to achieve safe and routine operations of civil unmanned aircraft systems; best methods to ensure safe operation of civil unmanned aircraft systems and public unmanned aircraft system simultaneously in the NAS," (Modernization Act, p. 64, 2012). These are only a few of the challenges faced by the FAA to integrate the UAS into the NAS and they revolve around the safe implementation of this new process. An issue that has plagued the UAS community for many years is the “sense and avoid” capability; because there is no human on board the aircraft, what is the most efficient and effective way for an unmanned aircraft to sense and avoid another aircraft? The Roadmap 2013 does discuss this challenge and is reference later within this study.

With regards to safety and integration of UAS into the NAS, the Reform Act ensures that there is an assessment of the UAS and how it will affect the safe operational requirements. The Reform Act states that, “if the Secretary determines under this section that certain UAS may operate safely in the NAS, the Secretary shall establish requirements for the safe operation of such aircraft systems in the NAS,” (Modernization Act, p. 67, 2012). To facilitate the Secretary’s decision, the Modernization Act states that there will be safety studies conducted to “support the integration of UAS into NAS,” (p. 68, 2012). Since 2014, one year from the Modernization and Reform Act’s implementation, a Google Scholar search for “safety studies of unmanned aerial vehicles” yielded over 7,870 results. Though many of these results may not be directly associated with the UAS integration into the NAS, it does show that there is an increased desire for knowledge and an ambition to ensure the safe operations of UAS. The number of studies done by the FAA with regards to the integration of the UAS into the NAS could not be determined.

## UAS Flight Operations in the NAS

The UAS has been predominantly used in the War on Terror over countries in the Middle East and Southwest Asia. During these flights, the UAS has been used to conduct surveillance to aid soldiers on the ground or to deliver weapons against known terrorists and insurgents. In Sep 2015, the NAS becomes available to UAS integration resulting in a large number of companies and government agencies preparing to begin UAS flight operations. Before these companies or individuals are authorized to fly a UAS, they must complete the process to legally fly their UAS as a public use or civil aircraft.

Public use aircrafts are classified as "an aircraft that is used only for government purposes; an aircraft that is leased or owned by the government and operated by any person for purposes related to crew training, equipment development, or demonstration" (sUAS News, 2012). A civil aircraft is "any aircraft except a public aircraft" (sUAS News, 2012). With these definitions in mind there are many different operators prepared to integrate their UAS into the NAS, some of the public use operators include the Departments of Agriculture, Commerce, Defense, Energy, Homeland Security, Interior, Justice, law enforcement agencies, state universities and NASA (Williams, 2011, p. 6). Civil use operators include Raytheon, AAI Corp, General Atomics, Boeing and additional research companies that are not named (Williams, 2011, p. 6).

Some of the flight operations conducted by these public and civil operators include training missions, operational missions in law enforcement capacity, research, sensor development testing, marketing, border patrol, firefighting, disaster relief and search and rescue (Williams, 2011, p. 7). Reported in 2010, the preponderance of applications for operations in the NAS came from the Department of Defense with 42%, followed by academia with 28% and other with 27% (Willis, 2010, p. 9).

After the announcement of the integration of the UAS into the NAS by September 2015, many concerns for safety arose from the public in which the FAA's response was

“The Act requires safe – not full – integration of the UAS into the NAS by September 2015; the UAS Integration Office continues to work on a number of issues which require resolution in order for safe integration to occur,” (Warwick, 2014). With the safety concerns in mind, the UAS Integration Office identified several different issues for which they needed to tackle, including but not limited to certification standards for detect-and-avoid systems, improving the collection of safety data, developing safety risk management documents and developing training for air traffic controllers (Warwick, 2014).

The safety concerns have grown since the 2012 Act announcement with the increase of UAS incidents occurring with “recreational drones” flying in and around major populated areas. To help curtail some of the safety concerns and issues that have plagued the UAS integration, the FAA proposed in February 2015 new rules that will regulate operations of small UAS (under 55 pounds) and micro UAS (under 4.4 pounds). The rules implement that an operator of a small UAS would have to be at least 17 years old, pass an aeronautical knowledge test and obtain an FAA UAS operator certificate (FAA, 2015). Additionally, the rules state that operator must always see and avoid manned aircraft, discontinue flight if it poses a hazard to other aircraft, people or property, assess weather, airspace restrictions and population, limit altitude to 500 ft and speed no faster than 100 mph and must stay out of airport flight paths and restricted airspace (FAA, 2015).

Yet even with the new guideline proposal, in January 2015 a man lost control of his small drone that subsequently crashed into South Lawn of the White House (NBC News, 2015), and as recently as September 2015 a small drone crashed into the stands of a US Open tennis match which caused a delay in tournament play. Furthermore, a drone crashed into the University of Kentucky Commonwealth Stadium scoreboard during pregame festivities (Gilbert, 2015). In the case of the US Open crash, the operator was arrested and charged with reckless endangerment and flying a drone outside of a legal area (The Verge, 2015). These three incidents were covered by the media and only spurred public opinion on the necessity for the 2012 Act to continue to be implemented and raise many additional questions on the ability for the FAA and law enforcement to ensure operators are following the guidelines set forth by the FAA. According to the FAA Aviation Safety Information Analysis and Sharing (ASIAS) page, between 2010 and 2014, there were a reported 104 UAS incidents and accidents reported by academia, law enforcement and research facilities that were operating UAS within the confines of their authorized operations; the actual number of incidents and accidents that have occurred since that same period cannot be accurately identified and nor can the number of legal and illegal uses of UAS within the same time period.

## UAS History

UASs come in different shapes and sizes and are used for a multitude of mission tasks (FAA, 2011, p. 1). They range from the size of a small bird to having a wingspan of a passenger jet (FAA, 2011, p. 1). UASs are used in law enforcement, the War on Terror, search and rescue, and for scientific purposes (FAA, 2011). Once a commodity of the United States, today there are 54 countries around the world that operate UASs (RTBOT); of the 54 countries 41 possess more than one variant of UASs (RTBOT). While Brazil, Pakistan, the United Kingdom, and the former Soviet Union operate over

25 variants of UASs each (RTBOT), this dwarfs in comparison to the United States, which operate approximately 155 variants of UASs by numerous private companies and government entities (FAA Fact Sheet, 2010).

UAS are not new equipment to aviation and have been around since as early as 1914. According to Sinclair UAS Training and Certification Center, “the modern era of UAS development began in 1914 with Elmer Sperry’s innovations in electronic gyroscopic navigation systems, which ultimately provided the technology that would allow an aircraft to maintain level and stable flight without the need for a pilot” (Sinclair, 2012). During World War I and World War II, UAS testing began to take shape and UAS were utilized for research and training, validating the operational use of radio-controlled drones. In the early 1960s the USAF began to realize the potential and importance of the UAS and “formed two new UAS programs for use in surveillance,” (Sinclair, 2012), that produced two UAS surveillance platforms that were utilized during the Vietnam conflict.

With the improvement in technological and communications capabilities the UAS has evolved from training and surveillance drones, to the offensive power during the US’s War on Terror in Iraq, Afghanistan and other contested areas around the world. The efficiency and capabilities of UAS, and its increased use in military, research and law enforcement, has caused many companies, research facilities and academic institutions to take notice of the potential uses. According to Sinclair (2015), “the potential for UAS in data collection, analysis and transmission increases by leaps and bounds; from meteorology to agriculture, and from geology to health sciences, (the UAS) is a resource that becomes more valuable as we discover new ways to use it.” This discovery will for certainly mean an increase in UAS certification requests and an increase of UAS within the NAS.

## Required UAS Safety Features

Title 49 of the United States Code and its subtitles refer transportation and air safety. "Title 49 USC §40103(b) states that 'The Administrator shall prescribe air traffic regulations regarding the flight of aircraft for:

- Navigating, protecting, and identifying aircraft,
- Protecting individuals and property on the ground,
- Using the navigable airspace efficiently, and
- Preventing collision between aircraft, between aircraft and land or water vehicles, and between aircraft and airborne objects (sUAS News, 2012).

The FAA has the duty to ensure the safety of air travel and currently has certain criteria in place to ensure this safety is upheld regarding manned aerial flight. With the integration of the UAS into the NAS, a new venture in safety concerns has been opened. The FAA is taking steps to ensure the safe integration of UASs:

> The FAA is laying the path forward for safe integration of civil UAS into the NAS. The roadmap will describe the research and development necessary for the FAA to develop standards and policy for safe integration. An evolved transition will occur, with access increasing from accommodation to integration into today's NAS, and ultimately into the future NAS as it evolves over time. (UAS Fact Sheet, 2011, p. 2).

Furthermore, the FAA has recruited the help of Radio Technical Commission for Aeronautics (RTCA), a Federal Advisory Committee, to answer two primary questions pertaining to safety: "(1) How will UAS handle communication, command, and control and (2) How will UAS "sense and avoid" other aircraft?" (UAS Fact Sheet, 2011, pg. 2). Currently, the FAA is conducting research to assist in the progress of UAS integration, but there are no specific safety standards written for the UAS to be approved for flight operations. Most UASs have implemented some type of safety equipment or software.

The list of safety equipment and software includes but is not limited to: (1) manual flight termination (parachute release), (2) return on link fail option retraces planned route in the event of link loss/failure, (3) in-flight terrain collision detection (based on terrain elevation model) gives audible warning that collision with terrain is immanent, (4) waypoint route checks for terrain collision and no line of sight (LOS), and (5) emergency landing point preset options for fully automated recovery during a link failure (Skycam UAV, 2012).

## UAS Airworthiness Requirements

The Federal Aviation Administration Modernization and Reform Act 2012 will allow the integration of the 155 variants to fly in the US NAS by 2015. This privilege will not be handed out to all UAS and UAS operators. The FAA stated:

> The NAS encompasses an average of more than 100,000 aviation operations per day, including air carrier, air taxi, general aviation, and military aircraft. There are approximately 18,000 air carrier aircraft and 230,000 active general aviation aircraft in the U.S (FAA, 2011, p. 1).

By adding an untold amount of UASs into the NAS the potential for midair collisions, flight into terrain and other accidents could increase dramatically. For the UAS to safely operate within the NAS, it must meet the FAA airworthiness requirements.

The FAA UAS office is currently under works to establish guidelines for airworthiness requirements of a UAS to operate in a designated capacity other than two certificates it currently issues:

> In no case may any UAS or OPA be operated in the National Airspace System as civil unless there is an appropriate and valid airworthiness certificate issued for that UAS or OPA. U.S. registration is a prerequisite for the issuance of a special airworthiness certificate to UAS and OPA. Currently, the FAA issues UAS and OPA two types of special airworthiness certificates: special flight permits and experimental certificates. (FAA, 2011).

The process undertaken to receive an airworthiness certificate is quite simple; the requester fills out a Form 8130-6 and forwards it to the FAA. If approved, the requester will receive a Form 8130-7, authorizing flight operations of the UAS under a special flight certificate or an experimental certificate. The FAA states, “A special flight permit may be issued for an aircraft that may not currently meet applicable airworthiness requirements but is capable of safe flight for the purpose of production flight testing new production aircraft” (Order 8130-34B, 2011, pp. 3-5). An experimental flight permit is described as UAS that is used in “research and development (R&D), crew training, and market surveys” (Order 8130-34B, 2011, pp. 3-4).

To receive a special flight certificate, the UAS must be ready and available for inspections deemed necessary by the FAA in accordance with FAA Order 8130.34B and required appendixes. The UAS must meet such requirements as containment, lost link and flight termination procedures outlined in 8130.34B, and a safety evaluation conducted by an FAA Aviation Safety Inspector (ASI). To meet the requirements for an experimental certificate, the UAS must be deemed in compliance with the FARs and provisions applicable to the use of the UAS in an experimental capacity. The ASI will determine if the UAS and the operator meet the applicable criteria and will conduct an inspection and evaluation to ensure the UAS meets airworthiness criteria.

Once the ASI deems the UAS capable of a special certificate for flight-testing, non-experimental, they will issue an 8130-7 that is valid "for the period of time specified in the permit." When issued, an experimental certificate is good for "1 year or less after the date of issuance." (Order 8130-34B, 2011, pp. 3-5)

## FAA Certification of Waiver or Authorization Process

According to the FAA, there are four ways a UAS can operate within the US:

1. Restricted within an active Warning or Restricted Area,
2. Private recreational area IAW Advisory Circular 91-57,
3. Special Airworthiness Certificate and
4. Certificate of Waiver or Authorization (Willis, 2010, p. 3).

A Certificate of Waiver is an official document issued by the FAA that authorizes certain operations of aircraft to deviate from a regulation but under conditions that ensure an equivalent level of safety. Section 91.905 lists the sections of Part 91 that can be waived (8900.1, 2012, p. 3). A Certificate of Authorization (COA) is an official document issued by the FAA to permit certain activities that require FAA approval but does not waive any regulations, for example, parachuting/sky diving demonstrations

The process for obtaining a COA is currently being streamlined by the FAA to ensure safe integration of UASs into the NAS. According to the FAA some of the processes to change include:

> "Establishing metrics for tracking COAs throughout the process and improving the on-time rate for granting an authorization, developed an automated, web-based process to streamline steps and ensure a COA application is complete and ready for review, and changing the length of authorization from the current 12-month period to 24 months" (FAA, 2012).

To obtain a COA, the requester must go online and complete an application. The application is reviewed by the FAA UAS Office which will than validate the application to be reviewed by Unmanned Aircraft Program Office (UAPO) who will concur or request revalidation. Once the COA application is validated by UAPO it is sent back to the UAS for final approval, this process takes upwards of 60 days from submittal to approval.

In a 2010 presentation by Randy Willis of the FAA, data on the number of COA submitted from CY2008 and CY2009 and early CY2010 are reviewed. In CY2008, 239 COA were submitted and the number jumped to 335 in CY2009 (Willis, 2010, p. 7), this was a 40% increase in one year. In 2010, there were 29 submissions as of February 22. The number of COAs approved were 164, 147, and 16 (Willis, 2010, p. 11) respectively. Data pertaining to the final numbers of COA submitted and approved for 2011 and 2012 were not available.

The increase in COA submittals proves the importance for a reliable approval process. So far the process is still being improved to ensure a safe transition for UASs into the NAS and according to the FAA "If the FAA disapproves a COA, the agency quickly addresses questions from the applicant and tries to provide alternative solutions that will lead to approval" (FAA, 2012).

## UAS Flight Training Requirements

Because a UAS may be as small as a child's model airplane and flown by a non-certified flight operations person, for the sake of the research conducted, the training requirements for a UAS pilot will be referenced from current government jobs and military careers seeking UAS operators. In most cases, a certified UAS pilot requires a current pilot certificate with the proper approved medical certificate. If the pilot meets these criteria, then based on the specific job and duties involved, there may be specific minimum requirements to be met prior to being authorized to pilot a UAS. In an online job posting by Avianation it stated:

> "Candidate must possess a current private pilot certificate with instrument rating, a minimum of 1500 hours total flight time and a minimum of 750 hours flying the MQ-1 and/or MQ-9. Individuals should also have at least two years of experience in a UAS program as well as previous experience as an MQ-1/9 instructor pilot. Weapons delivery experience is highly desired. Operational knowledge pertaining to UAS maintenance and PMATS scheduling is beneficial (UAS Pilot, 2009, p. 1)."

In the US Air Force, most pilots want to fly the aircraft from the cockpit and not from a computer screen hundreds of miles away from the "action." The surge of UAS into the military inventory and the high demand of UASs for the War on Terror have seen an increase in UAS Air Force pilots. According to a January 2009 Air Force Times article, the stated, "By 2012, the Air Force plans to increase the ranks of UAV pilots and air operations staffers to a total of 1,100. That is up from just over 450 Predator and Reaper operators today - and 180 just a couple of years ago" (Air Force Times, 2009). In August 2012, an article by the New American stated, "To date, there are reportedly around 1,300 people controlling the Air Force's arsenal of Reaper, Predator, and Global Hawk drones, and the Pentagon plans to add about 2,500 pilots and support crew by 2014" (Wolverton, 2012).

To increase the number of UAS pilots who meet future requirements, the Air Force changed the policy that UAS pilots were required to be current operational pilots. The new training program for UAS pilot training began in 2008; the Air Force Times stated, “the Air Force will send 10 percent of its undergraduate pilots directly to UAV training…the first class began November 21, 2008” (Air Force Times, 2009). To become an Air Force UAS pilot, a candidate must be selected for the career field from one of three commissioning sources, Reserve Officer Training Corps (ROTC), Officer Training School (OTS) or the Air Force Academy (USAFA). The candidate must take and score reasonably well on the Air Force Officer Qualification Test (AFOQT) pilot section, score well on the Basic Aptitudes Test (BAT), and receive recommendations from their commander.

Once selected the candidate will attend Undergraduate Pilot Training (UPT) where they are taught the basic skills for flying and flight operations. Since the Air Force has opened the selection for UAS pilots from traditional pilots to first time pilots, the training is changed according to Air Force Times: “Students will receive initial flight training at Pueblo, Colo., RPA instrument qualification, and a fundamentals course at Randolph AFB, Tex., and then instruction at one of the Air Force's RPA formal training units” (Air Force Times, 2010). An Air Force Times article continues on to state:

> During the 10-week course, instructors will prepare the officers to fly MQ-1 Predators and MQ-9 Reapers…The future RPA pilots must complete about 140 hours of academics, must pass seven tests and run through 36 missions on T-6 simulators, for 48 hours of training. In all, the entire RPA pilot pipeline is expected to take about a year (Tan, 2011).

Training for UAS pilots is rigorous in the US Air Force and private companies and government agencies are looking for UAS pilots with previous flight experience and/or experience flying UASs. According to the FAA, to operate a UAS the operator of the UAS must be trained in the operations of the UAS and if the UAS has an airworthiness certificate, the operator needs to have a valid pilot certificate (FAA, 2012).

When the UAS is fully-opened to the NAS in 2015, the training and requirements of the operators should be sufficient to calm safety concerns based on operator knowledge and experience.

# CHAPTER III

## Methodology

A mixed method approach was used to conduct this study. Mixed method procedure is defined as the collection and analysis of qualitative and quantitative data to find an answer to research question(s) or hypothesis. The purpose of this mixed methods study was to address the relationship between the safety concerns associated with the integration of the unmanned aerial system (UAS) into the National Aerospace System (NAS) and the safety record of the UAS.

A Convergent Parallel design was used to complete the study. Convergent Parallel is defined as the simultaneous collection of data and separate analysis of data with a comparison of each result to confirm or disconfirm the information. A good example of Convergent Parallel use referred to by Creswell (2014), describes a Convergent Parallel study conducted by Classen (2007) involving drivers 65 and older. Classen (2007) studied driver's safety in older drivers "in order to develop a health promotion intervention based on modifiable factors influencing motor vehicle crashes (Creswell, 2014, p. 233)." Using a Convergent Parallel design will help explain and validate any relationship between perceived safety concerns and actual safety issues. Figure 1 depicts the procedures to be used in the study.

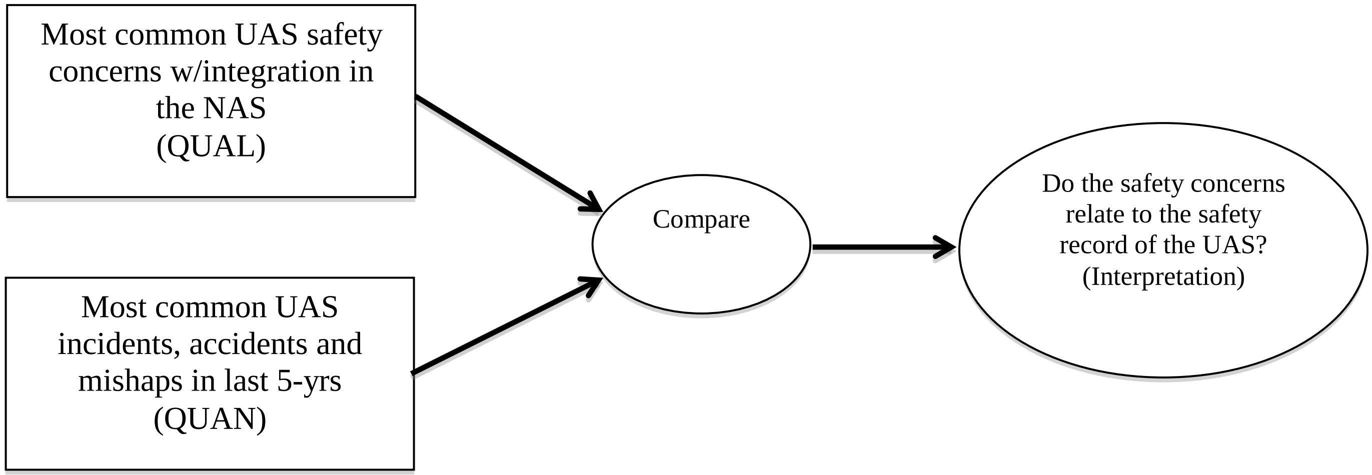


Figure 1. Convergent Parallel Design

The study consists of a qualitative approach to find the most common safety concerns with the integration of the UAS into the NAS. The quantitative approach was conducted to find the most common causes of UAS incidents, accidents and mishaps within the last five years through the use of online databases. The challenge with conducting this study was conducting the qualitative portion of the study on a large enough sample of the US population to garner significant results. This challenge was due to time allotted for the study, funding and the ability to reach out to a large enough sample population.

To receive expert opinions on safety, a qualitative research method consisted of interviews and questionnaires given to US Air Force UAS instructor and evaluator pilots and sensor operators. The information gathered from the qualitative approach was compared to the quantitative findings to see if a relationship between the safety concerns and safety records exists and if the concerns are valid. A mixed method approach to this study helps explain if a relationship existed between qualitative and quantitative findings.

## Quantitative Data Collection

This study referenced US Air Force (USAF), Navy (USN) and Army (USA) accident databases to complete the quantitative data collection on UAS accidents in the last five years and the most common causes for accidents. The information was solicited via Freedom of Information Act formal requests to the Navy and Army Safety Institutions. The Air Force data was compiled from the USAF Judge Advocate General public webpage. The information collected from all services was not always complete data due to the nature of the operations in which the UAS was used. The USN and USA did not provide specific dates or years, but did conform to the five year period in the study, while the USAF did provide that information. The data was compiled using a manual tracking method to conclude if there were specific factors for the preponderance of accidents, and to show any significant difference in the accidents based on operator factors or equipment factors.

## Quantitative Data Analysis

The data collected for the quantitative study was analyzed manually. Since the data was tracked manually, each accident was placed into accident class categories that included: USAF- Class A & Unknown; USN- Class A, B, C, H and USA- Class A, B, C, D, E. Within the class categories, the accidents were categorized by causal category: pilot error (PE), engine failure (E), loss of controls (CT), lost link (LL) and other (O). Additionally, causal categories were categorized by period of flight: takeoff (TO), cruise (CR), landing (L) and other (O). From the selected categories, the totals were added to find the most common causal for the accident and most common period of flight. Lastly, categories of impacts with structures, near midair and midair collisions were recorded by the researcher.

## Qualitative Data Collection

Seven US Air Force instructor and evaluator UAS pilots and sensor operators were recruited to support the qualitative data collection. Due to Air Force regulations, the pilots and sensor operators could not provide support during duty hours or from government computers so the researcher used private emails and phone numbers to forward the research survey and conduct the interview. The seven pilots and sensor operators that completed the survey were also asked to participate in the interview element of this study. To provide a scalable measure of concerns, a list of Likert Scale statements were addressed in the survey. The interviews were conducted to provide supporting data that could not be measured by the research survey.

## Qualitative Data Analysis

The qualitative data was collected in two manners: (1) Likert scale statements, (2) personal interviews of each pilot and sensor operator. The qualitative Likert scale statements and participant answers were created and compiled by use of an online survey service, Survey Monkey. The online survey database provided the capability to analyze data trends of answers. The database was able to provide support to find the mean, mode and median for each completed survey. The interviews were recorded, and transcribed for coding using computer software.

## Mixed Method Data Analysis

The quantitative data was collected using several databases to find the most accurate and current data. The data from the quantitative study was manually compiled to find the most common accident causals and period of flight, in addition to impacts with structures, near midair collisions and midair collisions for UAS in the last five years.

The qualitative data was collected through use of a research survey and personal interviews. The qualitative data was compiled manually and through the use of computer software coding. Between the quantitative and qualitative data, each answer was provided a number code and compiled into the specific section. For example, if one of the most common causes for UAS accidents was lost link it received a 1. Regarding the survey, if one of the most common concerns for accidents was lost link accidents with another aircraft, it was given a 1. Additionally, when interviewed, if the pilot or sensor operator stated that one of their concerns was lost link it was coded as 1. The data from each approach was then compared to find the relationship.

## Procedures for Missing Data

Due to the sensitivity of the data collected from the USAF, USN and USA, not all information was provided to the researcher. The researcher used the formal Freedom of Information Act process to garner information from each military service that uses the UAS on a daily basis. Since not all the information was provided by each service and the accident classes were not exactly the same, the researcher compiled like data into specific classes, combined all the data under a five year umbrella and combined each accident under specific causal and period of flight categories.

## Measurement of the Variables

For this mixed method study, the variables used for the quantitative portion were categorized by accident class, accident cause and period of flight. The variables used for qualitative portion of the study consisted of level of concern on a Likert Scale of 1-5.

## Validity Approach

The quantitative and qualitative data were collected and tracked manually. The quantitative approach consisted of data collected from accident databases to find the most common accidents causals and period of flight involving UAS over the last five years. The qualitative data was collected using a series of Likert statements and personal interviews with USAF instructor and evaluator UAS pilots and sensor operators and coded using computer software.

## Resources and Skills

This research study was initiated based on the researcher's experience with UAS during the War of Terror. The researcher served 13 years in the US Air Force and 11 of the years as an Air Battle Manager on board the E-3 Sentry (Airborne Warning and Control System) aircraft conducting command and control of aircraft to include UAS over contingency areas. From this experience, the researcher believed it prudent for research to be done based on the new regulation passage allowing integration of UAS in the NAS to show if concerns are legitimate based on the accident causes during flight of the UAS. Additionally, the researcher conducted an internship with the Oklahoma Flight

Standards District Office and received in depth knowledge and experience related to airworthiness and certifications of pilots and aircraft.

## Ethical Issues

Human participants were used during this study and approval was granted from the Institutional Review Board (IRB) at Oklahoma State University prior to conducting the study. Potential ethical issues discussed include personal disclosure of information from the USAF UAS pilots and sensor operators, perception of involuntary participation in the study, confidentiality issues involved with recording the interviews and legal differences in belief of the new regulation.

Each issue was discussed and ways were identified to alleviate each issue. A Privacy Act statement was provided for each questionnaire and prior to recording each interview. A statement of voluntary involvement was provided and signed by the research subjects prior to their participation in the study. Each research survey and personal interview included a Privacy Act statement and discussions of a legal nature were not associated to a pilot or sensor manager.

CHAPTER IV

## Findings

The purpose of this research was to identify, if any, relationship between the most common accidents types of unmanned aerial systems (UAS) and the safety concerns that UAS pilots and sensor operators possess for the integration of the UAS into the National Airspace System (NAS). This mixed method approach research project included quantitative data collection and analysis of the most common accidents and causes for accidents that occurred between June 2009 and June 2014. Additionally, the qualitative data collection and analysis was conducted using US Air Force (USAF) UAS pilots and Sensor Operators. The data collection included a Likert statement survey and personal interviews of pilots and sensor operators.

Between 2009 and 2014, there were 417 reported accidents by the US Air Force (USAF), US Navy (USN) and US Army (USA) involving UAS. Of those accidents, the USAF reported 45, USA reported 324 and the USN reported 48. Due to the sensitive nature of the UAS usage, not all services provided a breakdown of accidents by year, but provided the number of accidents and causes between the time-period requested 2009-2014. The USAF did break down accidents by years; these included 11 accidents in 2009, 7 accidents in 2010, 14 accidents in 2011, 10 accidents in 2012, and 3 accidents in 2013; 2014 numbers were not available at the time of this study. Each military service accident database was categorized into classes relevant to the specific service definition of accident class; Table 1 differentiates the numbers of accidents by class and service that were included in this study.

Table 1

*Accident Class Totals*

| | |
|---|---|
| **Air Force** | |
| *Class Totals* | ***45*** |
| *A* | 38 |
| *B* | 0 |
| *C* | 0 |
| *D* | 0 |
| *Unknown* | 7 |
| **Navy** | |
| *Class Totals* | ***48*** |
| *A* | 8 |
| *B* | 5 |
| *C* | 15 |
| *H* | 20 |
| *Unknown* | 0 |
| **Army** | |
| *Class Totals* | ***324*** |
| *A* | 35 |
| *B* | 72 |
| *C* | 159 |
| *D* | 57 |
| *E* | 1 |

## Accident Classes

There were 417 total UAS accidents reported in five distinct classes from 2009-2014 between these three US military services. Of the 417 UAS accidents included in the study, the stats show a disparity between accident numbers and classes between the three services. For example, the USAF and USA both had 38 and 35 Class A accidents during this time period, while the USN reported 8, but had 20 Class H accidents; the USAF and

USA did not provide Class H information. To help explain this disparity, the definitions of each class were included to show similarities and differences of accident types:

In accordance with AFI91-204 (2014, pp. 21-22), an Air Force Class A Mishap resulted in one or more of the following:

1. Direct mishap cost totaling $2,000,000 or more,

2. A fatality or permanent total disability,

3. Destruction of a DoD aircraft; Note: A destroyed Group 1, 2, or 3 RPA/UAS is not a Class A mishap unless the criteria in paragraphs (1) or (2) above, are met, and/or

4. Permanent loss of primary mission capability of a space vehicle.

A Class B Mishap resulted in one or more of the following:

1. Direct mishap cost totaling $500,000 or more but less than $2,000,000,

2. A permanent partial disability,

3. Inpatient hospitalization of three or more personnel. Do not count or include individuals hospitalized for observation, diagnostic, or administrative purposes that were treated and released, and/or

4. Permanent degradation of primary or secondary mission capability of a space vehicle or the permanent loss of secondary mission capability of a space vehicle.

A Class C Mishap resulted in one or more of the following:

1. Direct mishap cost totaling $50,000 or more but less than $500,000,

2. Any injury or occupational illness that causes loss of one or more days away from work not including the day or shift it occurred. When determining if the mishap is a Lost Time Case, you must count the number of days the employee was unable to work as a result of the injury or illness, regardless of whether the person was scheduled to work on those days. Weekend days, holidays, vacation days, or other days off are included in the total number of days, if the employee would not have been able to work on those days,

3. An occupational injury or illness resulting in permanent change of job, and/or

4. Permanent loss or degradation of tertiary mission capability of a space vehicle.

Lastly, a Class D Mishap resulted in one or more of the following:

1. Direct mishap cost totaling $20,000 or more but less than $50,000, and/or

2. Any mishap resulting in a recordable injury or illness not otherwise classified as a Class A, B, or C mishap.

In accordance with Army Regulation 385-10, Army Safety Program (2013, pp. 25-26):

> Unmanned Aircraft System (UAS) accidents are classified based on the cost to repair or replace the UAS. A destroyed, missing, or abandoned UAS will not constitute a Class A accident unless replacement or repair cost is $2 million or more (AR 385-10, 2013, p. 26).

An Army Class A accident occurs when:

1. The resulting total cost of property damage is $2 million or more,

2. An Army aircraft is destroyed, missing, or abandoned, or

3. An injury and/or occupational illness results in a fatality or permanent total disability.

An Army Class B accident occurs when:

1. The resulting total cost of property damage is $500,000 or more but less than $2 million,

2. An injury and/or occupational illness results in permanent partial disability, or

3. Three or more personnel are hospitalized as inpatients as the result of a single occurrence.

An Army Class C accident occurs when:

1. The resulting total cost of property damage is $50,000 or more but less than $500,000,

2. A nonfatal injury or occupational illness that causes 1 or more days away from work or training beyond the day or shift on which it occurred, or

3. Disability at any time (that does not meet the definition of Class A or Class B and is a day(s)-away-from-work case).

An Army Class D accident occurs when:

1. The resulting total cost of property damage is $20,000 or more but less than $50,000, or

2. A nonfatal injury or illness results in restricted work, transfer to another job, medical treatment greater than first aid, needle stick injuries, and cuts from sharps that are contaminated from another person's blood or other potentially infectious material, medical removal under medical surveillance requirements of an OSHA standard, occupational hearing loss.

Lastly, an Army Class E occurs when the resulting total cost of property damage is $5,000 or more but less than $20,000.

In accordance with Operational Navy Instruction (OPNAV) 3750.6S (2014, pp. 14-15), A

Navy Class A Mishap occurs when:

1. The total cost of damage to DoD or non-DoD property, aircraft or UAVs is $2 million or more,

2. A naval aircraft is destroyed or missing, or

3. Any fatality or permanent total disability of personnel results from the direct involvement of naval aircraft or UAV. A destroyed or missing UAV is not a class A unless the cost is $2 million or more.

NOTE: The Class A Mishap definition typically excludes group 1, 2 and 3 UAS and UAVs unless the mishap cost total is $2 million or more, or there is any fatality or permanent total disability of personnel.

Navy Class B Mishap occurs when:

1. The total cost of damage to DoD or non-DoD property, aircraft or UAVs is $500,000 or more, but less than $2 million, or

2. There is a permanent partial disability, or when three or more personnel are hospitalized for inpatient care (which, for mishap reporting purposes only, does not include just observation or diagnostic care) as a result of a single mishap.

Navy Class C Mishap occurs when:

1. The total cost of damage to DoD or non-DoD property, aircraft or UAVs is $50,000 or more, but less than $500,000, or

2. A nonfatal injury or illness results in one or more days away from work; not including the day of the injury.

Navy Class D Mishap occurs when:

1. The total cost of damage to DoD or non-DoD property, aircraft or UAVs is $20,000 or more, but less than $50,000, or

2. There is a recordable injury (greater than first aid) or illness results not otherwise classified as a class A, B, or C mishap.

The disparity between classes was noted due to the dollar amount for the UAS used by each service. The USAF reported UAS accidents involving the MQ1B, MQ9, EQ4 and QRF-4C aircraft, illustrated in Figure 2 through Figure 5. The UAS involved in each accident and the unit cost for each aircraft is listed in Table 2. For example, each UAS is valued over the $2,000,000 amount listed in the Class A definition (AFI91-204), thus 38 accidents involving UAS for the USAF during the time period researched were Class A and the seven not listed as Class A were unknown due to the lack of information on cost for repair of the UAS.

The USN reported accidents involving BQM74, K-MAX, MQ-001L, MQ-008B, MQ-9, RQ-1, RQ-2B, RQ-4A, RQ-7B, RQ-21B, RQ-23 and SCAN EAGLE. The UAS operated by the USN and involved in this study are shown in Figure 6 through Figure 16 and the unit cost values are listed in Table 3. The USA reported accidents involving MAV, MQ-1B, MQ-1C, MQ-5B, RQ-11, RQ-11B, RQ-7, RQ-20A and RQ-12A (WASP3). The UAS operated by the USA and involved in this study are shown in Figure

17 through Figure 21 and the unit cost values are listed in Table 4. All figures have received permission for reproduction in this research study (Terms of Use, 2014).

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Figure 2. US Air Force MQ1B

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 3. US Air Force MQ9

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 4. US Air Force EQ4

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 5. US Air force QRF-4C

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 6. US Navy BQM74

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 7. US Navy K-MAX

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 8. US Navy MQ1L/RQ1

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 9. US Navy MQ8B

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 10.  US Navy MQ9

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 11.  US Navy RQ2

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 12.  US Navy RQ4A

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 13.  US Navy RQ7B

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 14.  US Navy RQ21B

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 15.  US Navy RQ23

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 16.  US Navy SCAN EAGLE

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 17.  US Army MAV

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 18. US Army MQ1B/MQ1C

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 19. US Army MQ5B

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 20. US Army RQ11/RQ11B

IMAGE © COMMONS.WIKIMEDIA.ORG

Figure 21. US Army RQ-12A (WASP3)

Table 2

*US Air Force UAS Value*

| UAS TYPE | UNIT COST |
|---|---|
| MQ1B | $4.03 Million: 2010 unit cost (FY11 Presidential Budget, 2009) |
| MQ9 | $16.9 Million: 2013 cost (FY13 Presidential Budget, 2012) |
| EQ-4 | $131.4 Million: 2013 unit cost (GAO, 2013) |
| QRF-4C | $2.8 Million (acc.af.mil, 2011) |

Table 3

*US Navy UAS Value*

| UAS TYPE | UNIT COST |
|---|---|
| BQM74 | $405,000: 2015 cost (Wikipedia.com, 2015) |
| K-MAX | $5.0 Million: 2015 cost (Axlegeeks.com, 2015) |
| MQ1L | $4.03 Million: 2010 unit cost (FY11 Presidential Budget, 2009) |
| MQ8B | $10.81 Million: 2013 cost (Aeroweb, 2015) |
| MQ9 | $16.9 Million: 2013 cost (FY13 Presidential Budget, 2012) |
| RQ1 | $4.03 Million: 2010 unit cost (FY11 Presidential Budget, 2009) |
| RQ2 | $850,000: 2012 cost (SUASNews, 2012) |
| RQ4A | $131.4 Million: 2013 cost (GAO, 2013) |
| RQ7B | $750,000: 2011 cost (Oestergaard, 2013) |
| RQ21B | $9.6 Million: 2014 cost (Budget Activity, 2013) |
| RQ23 | Unlisted |
| SCAN EAGLE | $3.2 Million: 2006 cost for 4 drones & systems (Boeing, 2011) |

Table 4

*US Army UAS Value*

| UAS TYPE | UNIT COST |
|---|---|
| MAV (Micro Air Vehicle) | Costs Vary |
| MQ1B/MQ1C | $4.03 Million: 2010 unit cost (FY11 Presidential Budget, 2009) |
| MQ5B | Unlisted |
| RQ11/RQ11B | $35,000: 2014 cost (Army-Tech, 2015) |
| RQ7 | $750,000: 2011 cost (Oestergaard, 2013) |
| RQ20A | approx. $250,000: 2014 cost (Wikipedia, 2014) |

| | |
|---|---|
| RQ-12A (WASP3) | approx. $49,000: 2014 cost (Wikipedia, 2014) |

Figure 22 provides the reported UAS accidents by class from 2009-2014 timeframe.

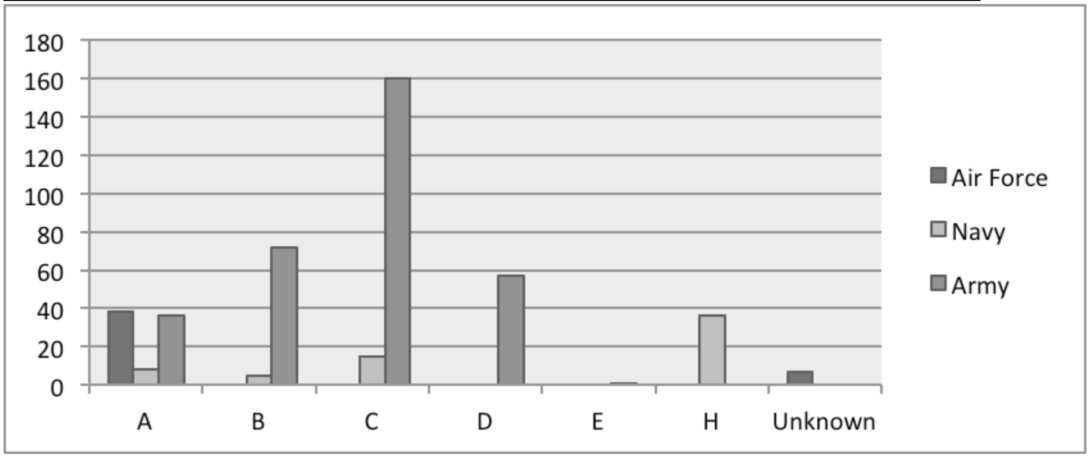


Figure 22. Accident by Class

Within each class each accident was further categorized by accident cause and period of flight. The accident cause categories included: pilot error (PE), engine (E), loss of control (CT), lost link (LL) and other (O). The period of flight categories included: takeoff (T/O), cruise (CR), landing (L) and other (O).

## Quantitative Findings

The following research objective guided this study:

> Based on the most common UAS accidents causes and US Air Force UAS instructor and evaluator pilots and sensor operators, is there a significant relationship between safety concerns and safety issues?

The following research questions guided the quantitative research of this mixed method study:

1. What safety feature prevents UAS midair collision?
2. How many times has this safety feature prevented midair collisions?
3. What safety feature prevents accidents during lost link events?
4. How many lost link incidents have occurred ending with accidents?
5. How many lost link incidents have occurred ending without accidents?
6. What are the most common UAS accidents within the last 5 years?
7. Have UAS meeting airworthiness requirements been involved in more accidents than UAS not meeting airworthiness requirements?

Safety Concerns and Safety Issues Relationship

From 2009 to 2014, the three military branches observed in this research study reported accidents caused by pilot error (PE), engine failure (E), loss of control (CT), lost link (LL) and other (O). Figure 23 provides the most common accident causes by service, while Figure 24 provides the total number of accidents by cause over the five-year period.

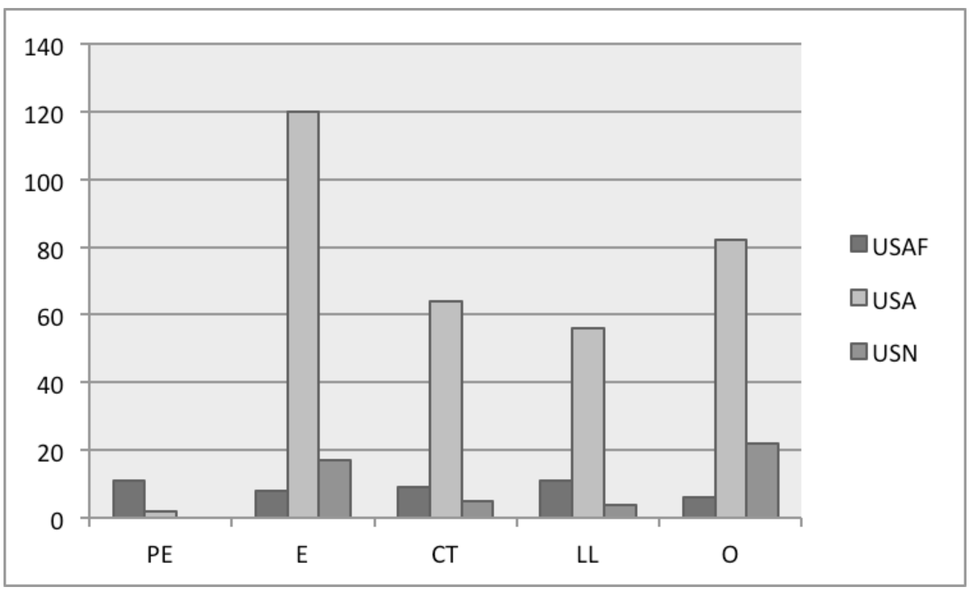


Figure 23. Most Common Accident Causes by Service

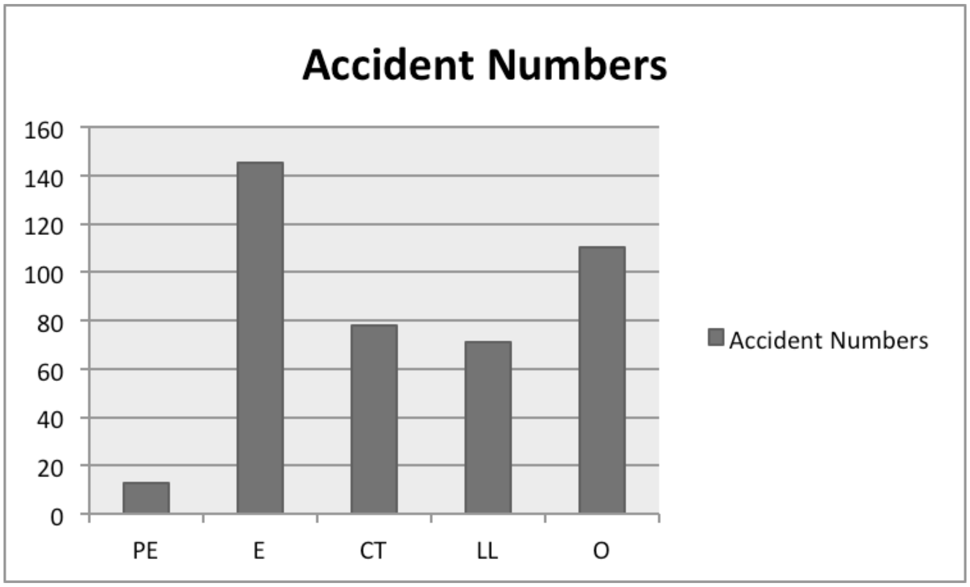


Figure 24.  Most Common Accident Causes Totals

**Safety Concern**

Seven UAS pilots and sensor operators from the USAF completed the research survey.  The survey consisted of 33 Likert-scale statements relating to flight experience, flight safety concerns during phases of flight and safety concerns with regards to UAS sharing the airspace with commercial airliners.

After collecting the data from the accident databases, this data and the responses to the Likert statements were compared using observations of the data.  Observation of the data consisted of data comparison, was conducted to discover if there were any relationship between safety concerns and safety accidents.  Comparison between the most common accidents during the three phases of flight and the level of safety concerns that each research subject had for accidents to occur during those phases of flight was completed.  UAS flight profiles were categorized into takeoff, cruise and landing and the most common accidents divided into the respective phase of flight.

## Research Questions

What safety feature prevents UAS midair collision?

While conducting this study, the researcher identified 15 near mid-air collisions and two mid-air collisions from 2009-2014 reported by the USN and the USA. The USN reported 15 near mid-air and zero mid-air collisions; and there were no fatalities or injuries in any of the cases reported, while the USA reported two mid-air collisions. The USAF did not report any near mid-air or mid-air collisions.

To avoid mid-air collisions, commercial airlines use a Terrain Collision Avoidance System (TCAS). The TCAS uses transponder information from surrounding aircraft to provide the pilots information on developing safety situations. It additionally uses Terrain Advisory Line (TAL) to provide pilots timely information to avoid pending collisions with terrain. However; currently, UAS do not have TCAS or the capability to see and avoid other aircraft. See and avoid is defined in CFR 14 91.113 as:

> "When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear." (CFR 14 91.113, 2015).

According to the FAA (2013) document, "Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap," "sense and avoid (SAA) capability must provide for self-separation and ultimately for collision avoidance protection between UAS and other aircraft analogous to the 'see and avoid' operations of manned aircraft that meets an acceptable level of safety," (FAA, 2013, p. 19).

Additionally, the FAA continues to state that, "unmanned flight will require new or revised operational rules to regulate the use of SAA systems as an alternate method to comply with see and avoid operational rules," (FAA, 2013, p. 19). With this in mind, currently not all UAS systems have a SAA or see and avoid capability.

Technologically advanced UAS, such as the MQ-4 and other militarily used UAS, utilize cameras for the operators but these cameras are only able to see a specific amount of view. To support the SAA and see and avoid concept, UAS aircraft and UAS pilots would have to acquire and develop a "see and avoid, radar, visual sighting, separation standards, proven technologies and procedures and well-defined pilot behaviors," (FAA, 2013, p. 19) to ensure safety of flight. To support the SAA and see and avoid policies, new technology with new piloting processes and procedures need to be developed. Currently, Ground Based Sense and Avoid (GBSAA) and Airborne Sense and Avoid (ABSAA) concepts and procedures are being studied and evaluated by public agencies and commercial companies (FAA, 2013). These new concepts and procedures should help support future development of safety procedures for UAS.

How many times has this safety feature prevented midair collisions?

After gathering all possible data from the databases and the participants, the researcher was unable to determine the number of occurrences that the TCAS helped prevent flight into terrain or another aircraft. Additionally, with the lack of sense and avoid capability, this data was not able to be collected.

What safety feature prevents accidents during lost link events?

Not all UAS have safety features for a lost link scenario; however, all UAS identified in this research study have a built in safety feature for lost link incidents. Lost link as defined by the Federal Aviation Administration (FAA) is, "Loss of command and control link between control station and aircraft" (FAA, 2013). The safety feature is programmed to direct the UAS to waypoints in route to its home station if it loses link to its host.

During this study, it was determined there were 71 total lost link occurrences reported from the USAF, USN, and USA. According to the FAA Roadmap (2013), "air traffic products, policies and procedures need to be reviewed and refined or developed through supporting research to permit UAS operations in the NAS," (FAA, 2013, p. 17). These products, policies and procedures include operations and contingency procedures for UAS experiencing lost link events. The FAA has incorporated human factors into their contingency plan for dealing with lost link events, categorizing lost link events under "Predictability and contingency management," (FAA, 2013, p. 30) research challenge. To date, the more advanced UAS, such as the MQ-4B, utilize preprogrammed procedures in the event of lost link. Graph 4 provides the number of lost link incidents by service and class.

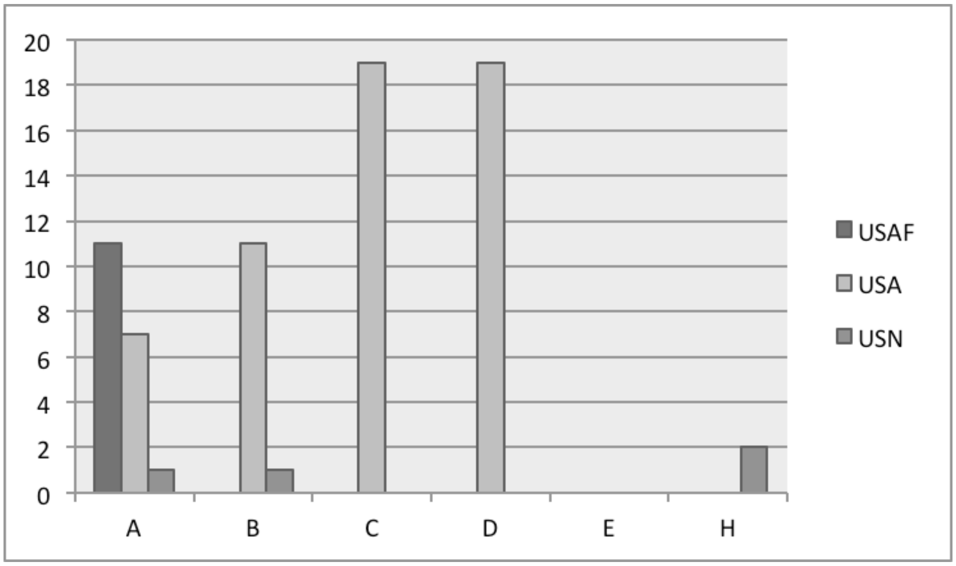


Figure 25. Lost Link

How many lost link incidents have occurred ending with accidents?

As mentioned, there were 71 lost link incidents between the USAF, USA and USN, All 71 of the reported lost link incidents resulted in terrain or crash landings.

How many lost link incidents have occurred ending without accidents?

All 71 lost link incidents between the USAF, USA and USN ended with flight into terrain or crash landings; therefore, none of the UAS were reported to have landed safely.

What are the most common UAS accidents within the last 5 years?

The most common UAS accidents identified in this study were attributed to pilot error, engine failure, loss of control, lost link and other causes (weather, electrical, runway overrun, etc.). Of these common causes, the most common accident cause was engine failure. From 2009-2014, there were at total of 145 engine failure incidents that resulted in a crash of a UAS. The Army (USA) led the incident field with 120 reported engine failures that resulted in a Class A, B, C or D accident. Most of the USA accidents resulted in a Class C incident (74), which made up 47% of all Class C USA accidents reported (159). Graph 5 illustrates engine failure by military service and UAS class.

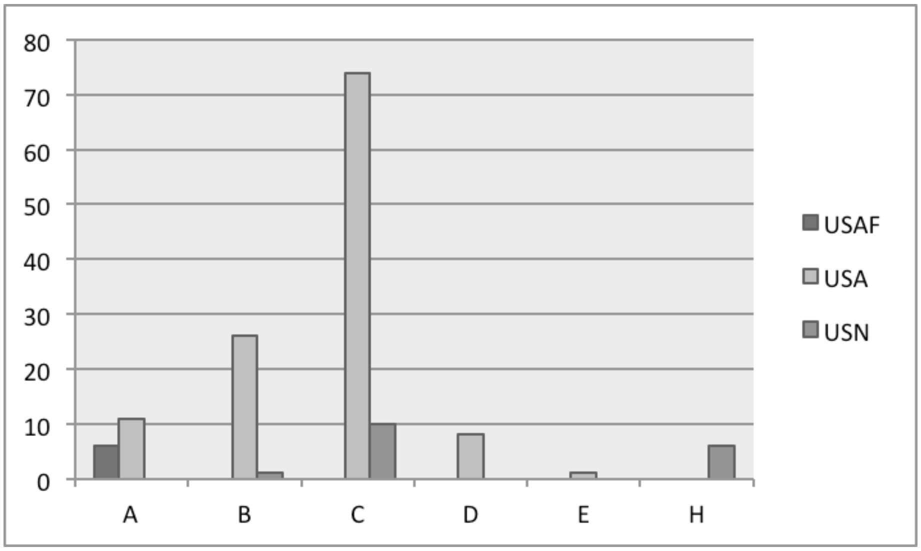


Figure 26. Engine Failure

Have UAS meeting airworthiness requirements been involved in more accidents than UAS not meeting airworthiness requirements?

All UAS accident reports identified for this research study involved military use UAS. All military UAS have to meet strict airworthiness standards set by the Department of Defense in accordance with Department of Defense Directive 5030.61 (2013). For operations of UAS within the US NAS, a UAS will receive airspace access through issuance of Certificate of Waiver or Authorization and through receipt of a special airworthiness certificates, as mentioned earlier in this research. The FAA Roadmap (2013) states that in the future, "COAs and special airworthiness certificates will transition to more routine integration processes when a new revised operating rules and procedures are in place and UAS are capable of complying with them (FAA, 2013, p. 5).”

The Roadmap (2013) elaborates that “to gain full access to the NAS, UAS need to be able to bridge the gap from existing systems requiring accommodations to future systems that are able to obtain a standard airworthiness certificate (FAA, 2013, p. 6).” This means that there needs to be a standard between all UAS operating with the NAS so they all meet safety standards outlined by the FAA. Additionally, not only will the unmanned aircraft itself meet these “airworthiness standards,” but so will all entailed with the unmanned system, i.e. control station, data link and unmanned aircraft. Ideally, with a safety standard in place and adhered to by all UAS receiving a standard airworthiness certificate, safe flight operations should increase with the number of UAS flying within the NAS.

To support meeting the certificate of waiver or authority process and to help mitigate the See And Avoid (SAA) issue that UAS will have, “some public agencies and commercial companies are seeking to develop advanced mitigations, such as Ground Based Sense and Avoid (GBSAA); test evaluations will help develop the sensor, link, and algorithm requirements that could allow GBSAA to function as a partial solution set for meeting SAA requirement (FAA, 2013, pp. 28-29).” With the introduction of GBSAA and the continued work towards Airborne Sense and Avoid (ABSAA) concepts, the requirement for UAS to meet certification of waiver and authority requirements should make UAS flight operations safer.

## Qualitative Findings

The following inferential research questions guided this qualitative research method of the mixed method study:

1. How do current (Independent Variable 'IV') and proposed (IV) safety features integrated into a UAS prevent the most common accident (Dependent Variable 'DV') occurrences?

2. Does UAS pilot training (IV) reduce the number of UAS accidents (DV)?

To support the qualitative research method of this study, a 33-question Likert-Scale survey along with a follow up interview was conducted to support the inferential findings.

## Inferential Questions

1. How do current (Independent Variable 'IV') and proposed (IV) safety features integrated into a UAS prevent the most common accident (Dependent Variable 'DV') occurrences?

Since there are many different types of UAS utilized today, the inferential findings will utilize the RQ-1 to support the IV and DV of this section. The RQ-1 was selected because it is currently in use by the USAF, US Navy, Customs and Border Patrol as well as other US agencies that may utilize it in the future within the NAS. The RQ-1 systems that support its flight operations and act as current safety features (IV) include an "inertial navigation system, satellite communications, Identification Friend or Foe (IFF) transponder, primary & secondary control modules, electro-optical infrared sensor and synthetic aperture RADAR (SAR)," (Valdes, 2015, p. 2). In conjunction with each other, these units provide some safety features for the UAS as it is more advanced than most commonly used UAS. The IFF allows for flight following (IV), the satellite communications allows beyond-line-of-sight control of the aircraft (IV), the optical cameras (IV) ensure the pilot can see in front of and to the side of the aircraft during day and night time operations and the SAR (IV) supports terrain mapping and "seeing through haze, clouds or smoke," (Valdes, 2015, p. 3).

Though there is an array of equipment to support the safe operations of the UAS, they do not make up for a pilot actually being inside the aircraft. The camera that are used for the RQ-1 is limits to their side to side movement and UAS pilots have likened flying the aircraft to "flying an airplane while looking through a straw," (Valdes, 2015, p. 6). This sight limitation adds to the See and Avoid (SAA)/ (IV) safety issue that FAA is currently trying to overcome. In addition to the SAA challenge, the RQ-1 does not carry a Terrain Collision and Avoidance System (TCAS)/ (IV). Without TCAS the UAS pilot as well as other piloted aircraft within the NAS are unable to know they are on a collision heading. During the quantitative research of this study, the US Navy reported 15 near midair collisions (DV), the US Army reported two midair collisions (DV) and the US Air Force did not report any near midair or midair collisions.

To support the qualitative findings of the study, the research subjects were interviewed and asked specific questions pertaining to safety concerns with integrating UAS into the NAS. One of the questions posed to the research subjects was "based on your answers to the UAS safety questionnaire, describe in your professional opinion the top three greatest concerns you have with the integration of the UAS into the NAS?" Research Subject #3, the lead Evaluator Pilot for MQ-1 flight operations, stated one of the greatest concerns was, "the lack of TCAS (IV)." An additional question posed to the research subjects was how to rectify their concerns; Research Subject #3 stated, "until the equipment evolves and we have onboard sense and avoid (IV), the current processes utilized by the USAF (IV) are adequate to reduce risk."

The results of the quantitative study within this researched yielded that the most common accidents occurred due to engine loss (DV) during cruise. The resulting accidents were due to loss of power (DV) and ended with partial or total destruction of the craft. In one case, a US Army UAS lost link during landing and struck a vehicle on the highway, resulting in a Class B accident. In this case the safety features in place were not adequate to prevent an accident involving property on the ground; no one was injured during this accident.

2. Does UAS pilot training (IV) reduce the number of UAS accidents (DV)?

The FAA Roadmap (2013) highlights the importance of training to help increase safety. The Roadmap (2013) emphasizes the importance of pilot training but also continues to require training for flight crewmembers, mechanics and air traffic controllers. The FAA recognized that for safe operations to occur for UAS flights, it does not only involve the pilot but also the members that are behind the scenes such as sensor operators, crew chiefs and the controllers that over watch the airways. The Roadmap (2013) details the training requirements for each of these members and explains, "UAS training standards will mirror manned aircraft training standards to the maximum extent possible," (FAA, 2013, p. 28). According to Research Subject #3, "the second most important issue is training (IV); there is a misconception that less training is required to pilot an RPA. I can tell you from experience that is not the case due to the reduced situational awareness (SA) and inherent delay in the RPA operations." It is evident that training is vital to the safe operations of the UAS.

The FAA Roadmap (2013) identifies pilot training as a significant requirement for UAS integration into the NAS. The Roadmap states, "as new UAS evolve, more specific training will be developed for UAS pilots, crew members and certified flight instructors," (FAA, 2013, p. 33). The Roadmap designated a section to iterate the goals for UAS training requirements and provides a metrics to support:

"UAS training standards will mirror aircraft training and standards to the maximum extent possible, including appropriate security and vetting requirements, and will account for all roles involved in UAS operation. This may include the pilot, required crew members such as visual observers or launch and recovery specialists, instructors, inspectors, maintenance personnel, and air traffic controllers. Accident investigation policies, processes, procedures and training will be developed near-term, and will be provided to Flight Standard District Offices (FSDO) for implementation. Existing manned procedures will be leveraged as much as possible, though difference will need to be highlighted and resolved." (FAA, 2013, p. 28)

The FAA roadmap does not take into account the training that US military UAS pilots receive, and in many cases Air Force UAS pilots are previously trained manned aircraft pilots that have been selected for special duty as a UAS pilot. As previously mentioned, USAF UAS pilots require "to complete about 140 hours of academics, must pass seven tests and run through 36 missions on T-6 simulators, for 48 hours of training (Tan, 2011)." The FAA is taking steps by including pilots, crew, maintenance, instructors, and FSDO to ensure the proper and adequate training for all involved with UAS flight within the NAS.

Research Subject #3 describes that one of the greatest concerns for the integration of the UAS in the NAS is "lack of training for most, smaller UAS operators." Research Subject #3 stated that "this is not the time to develop UAS 'sport pilot' equivalent certificate for any civilian operated quad-copter or smaller platform…but due to system limitations inherent to most UAS, including reduced ability to sense and avoid, solid training and procedures are required to safely integrate within the NAS." Research Subject #2, a Senior Pilot and Evaluator Pilot for the MQ-9 as well as F-16 and EA-6B, echoes Subject #3 with regards to training. Research Subject #2 stated that to rectify concerns would be to "educate the aviation community as a whole about UAS operations, in particular education should focus on capabilities and limitations of the RPA and about the training the pilot receives." Research Subject #2 continued to state, "the FAA/ATC can take many lessons on RPA incorporation with manned aircraft and operations in the NAS from the military. Specifically, they can model civilian operations after the operations from major operating airfields and airspaces in combat areas." The FAA Roadmap (2013) seems to take this into account as they have included training for more than just the pilot, crew and ATC. The Roadmap (2013) states that the UAS pilots must be trained as would a manned aircraft pilot, but this training may not be adequate enough and should go above and beyond.

As Research Subject #2 stated the capabilities and limitations of the UAS must be educated to the aviation community; Research Subject #3 stated that training is vital and "RPA pilots need to have a base of experience on which to relate," Subject #3 stated that "when piloting an RPA, it's impossible to 'feel' the sensation of the aircraft oscillating (during turbulence) and the pilots must rely on experience and their instruments to diagnose this." Educating and training pilots is essential in the safe operations of the UAS in the NAS, and training policies set by the FAA should mandate these training requirements that build on experience and knowledge.

To guide the qualitative method of the study, the researcher utilized inferential research questions, which are defined by Laird Dissertation (2015) as, "techniques that allow us to use these samples (smaller sample of larger groups) to make generalizations about the populations from which the samples were drawn." In this study, the research subjects were UAS pilots and sensor operators selected from the larger group of USAF UAS pilots and sensor operators.

## Research Subject Survey

To gather the qualitative information required for this mixed method research study a 33 Likert-scale questionnaire designed to solicit the pilots' and sensor operators' knowledge of UAS was utilized. The survey also collected information on experience and concern with the integration of the UAS in the NAS from the research subjects. Seven UAS pilots and Sensor Operators completed the survey. The interview portion of the qualitative study was completed with three of the pilots that completed the research survey and included seven questions designed to allow the pilots to provide additional insight into their concerns with the integration of UAS into the NAS; the interviews were conducted via email due to locality limitations. The next section of this research paper discusses the Likert Scale Survey utilized to gather the qualitative answers from the seven research subjects. The sections will discuss the answers gathered to each of the questions and provide the level of concern associated with each question and section of the survey.

To establish the credibility of the research subjects involved with this study, the first section of the survey queried the research subjects on their "Knowledge and

Understanding," with regards to UAS and manned aircraft operations and safety within the NAS. The first eight statements focused on the subjects' experience, knowledge and understanding of UAS, manned aircraft safety features and the NAS. The participants had five possible responses with regards to knowledge and understanding: 1 – None, 2 – Some, 3 – Well, 4 – Very Well, and 5 – Expert. All seven participants provided responses with an overall knowledge and understanding mean of 4.04 (Fig 5), amounting to a "Very Well" per the Likert-Scale statements. Of the seven participants, four answered level 5 (expert) for knowledge and understanding of UAS capabilities, three answered level 5 for understanding operations of aircraft safety features (one answered level 2 and one answered level 3), two answered level 5 for knowledge of UAS safety feature requirements and only one was an expert for knowledge of civilian aircraft safety features.

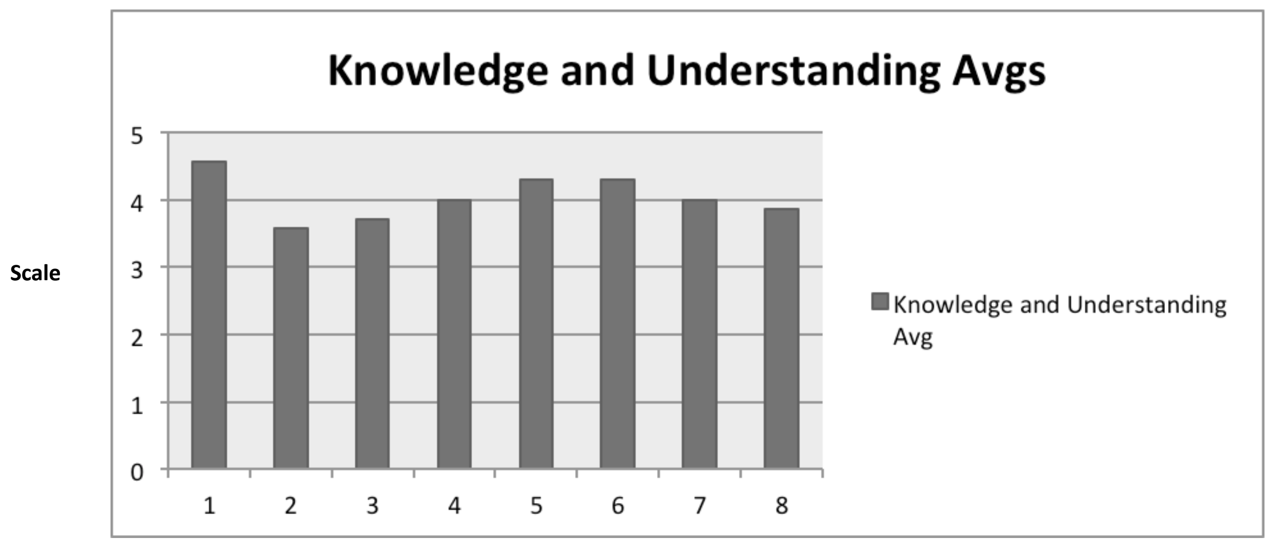


Figure 27. Knowledge and Understanding

The mean for the seven members regarding understanding and knowledge of the NAS (Table 5) was level 4, with two members answering level 3, three participants answering level 4 and two participants answering level 5. No participant answered level 1 (none) for any of the first eight questions. Though not all members were experts with respect to safety features for civilian and UAS aircraft and operations within the NAS, the overall average of level 4, indicates that each member has a very good knowledge and understanding of UAS operations and NAS requirements.

Table 5

*Knowledge and Understanding of NAS*

| **Level of Concern** | **Subject Answers** |
|---|---|
| 1 | 0 |
| 2 | 0 |
| 3 | 2 |
| 4 | 3 |
| 5 | 2 |

The next 21 survey statements focused on safety and concerns related to flight operations in different stages of flight, accidents involving UAS during different stages of flight, UAS accidents due to mechanical, electrical issues and concern of UAS accidents based on NAS oversaturation. For the safety portion of the survey, the Likert-Scale statements consisted of rankings: 1 – Not at all concerned, 2 – Slightly concerned, 3 – Moderately concerned, 4 – Very concerned, and 5 – Extremely concerned. The overall mean for this section was 1.83 (level 2, slightly concerned) and Table 6 displays the mean answer for each question of the safety section of the questionnaire.

The first three statements of the safety section of the survey focused on the research subjects' concern with safety of flight within the United States and saturation of the NAS. When asked if the subject believed domestic flights are unsafe, all seven answered the question with a mean concern level of 2 (Slightly concerned). When questioned about the current oversaturation of the NAS day to day, all seven participants answered with a mean concern level of 2. The next sets of questions focused on safety concerns and phases of flight.

Table 6

*Safety Concerns Questionnaire*

| **Safety Concern Section** | |
|---|---|
| **Question #** | **Mean Answer** |
| 9 | 2 |
| 10 | 2.57 |
| 11 | 2 |
| 12 | 2 |
| 13 | 1.86 |
| 14 | 2.14 |
| 15 | 1.43 |
| 16 | 2.29 |
| 17 | 1.71 |
| 18 | 1.71 |
| 19 | 1.71 |
| 20 | 1.71 |
| 21 | 1.71 |
| 22 | 2.29 |
| 23 | 1.86 |
| 24 | 1.43 |
| 25 | 1.57 |
| 26 | 1.43 |
| 27 | 1.71 |
| 28 | 1.71 |
| 29 | 1.5 |

The research subjects were questioned about safety concerns with regards to aircraft accidents involving a UAS during three phases of flight (takeoff, cruise and landing), the average level of concern between the seven subjects were 1.71, or level 2. The participants were then questioned with regards to an UAS accident occurring during a lost link event, all participants responded, with a mean level of concern being 1.71. Two participants answered they were “Not at all concerned” (level 1) and the remaining five answered they were “Slightly concerned” (level 2). The next two questions pertained to UAS accidents involving midair or structure collisions. All seven participants answered the midair collision question, resulting in a mean level of concern being 2.29. When questioned about the increase of potential accidents with terrain (homes, buildings, roads and populated areas), all seven participants responded that resulted in a mean level of concern of 1.86.

The final section of statements posed to the seven participants focused on safety concerns with regards to an increase of congestion with UAS in the NAS. When questioned about an increase in aircraft accidents with a UAS during takeoff, cruise and landing, the participants averaged concern response were 1.43, 1.71 and 1.43 respectively with an overall mean of 1.523 (level 2). The research subjects were surveyed on their concern with regards to knowledge of UAS safety features (mean of 3.71 from Knowledge & Understanding) and concern for airspace safety; all seven participants answered providing a mean level of concern at 1.71. Again, the participants were surveyed on a lost link scenario and all answers provided a mean of 1.71, no change from an earlier statement pertaining to lost link accidents. The final statement in the safety section of the questionnaire pertained to an increase of midair collisions when UAS are introduced into the NAS, the mean for this question was 1.50.

The phases of flight statements were posed to the research subjects on three different occasions, with the cruise phase being posed four times. The phases of flight statements were asked with levels of concern of pertaining to accidents currently with commercial aircraft, with UAS aircraft, possible increase in overall accidents and finally with a possible increase of accidents with an UAS. Respectively the mean of the total from each of these sections were 1.95, 1.71, 1.47 and 1.50.

The final portion of the survey related to the research subjects' demographics. There was not much difference with each research subject, one participant was in his or her 20s, one was in his or her 40s and five were in their 30s. Six of the participants were Caucasian and one was Asian. All research subjects held a Master's Degree and all had flown commercially more than 20 times in their lifetime.

## Mixed Method

Research Objective #1: Based on the most common UAS accidents causes and US Air Force UAS instructor and evaluator pilots and sensor operators, is there a significant relationship between safety concerns and safety issues?

The most common UAS accident causes discovered during the quantitative research involved UAS accidents experiencing some type of engine failure during flight. There were 145 engine event related accidents between the three military services researched with 95 occurring during the cruise stage of flight, this was double the amount of the next two common accidents, loss of controlled flight (78) and lost link incidents

(71). Unfortunately in the online survey provided, there were no questions pertaining to engine failure and the potential for accidents with a UAS during this event. When questioned about lost link events, the average level of concern between the seven pilots and sensor operators participating was 1.71 (level 2), “Slightly Concerned.” When the three research subjects were interviewed about their greatest concerns of the UAS integration into the NAS, no research subject answered engine failure as a level of concern. The three subjects had differing opinions of the three greatest concerns, they were as follows:

Research Subject #1

- Tremendous growth of micro UAVs and certification process required to operate them
- Public misunderstandings of UAS capabilities
- Public capability expectations of UAS

Research Subject #2

- Overall perception that UAS cannot be safely de-conflicted from manned aircraft
- Misconception of increased airspace requirements for UAS
- Misunderstanding of naming convention of UAS in “Lost Link” event and ATC use of terms--when in a lost link event, the UAS goes into “Emergency Mission Mode” and follows way points to designated area; this does not mean the UAS is an “Emergency Aircraft.”

Research Subject #3

- Lack of training for most, smaller UAS operators
- For USAF Remotely Piloted Aircraft (RPA), the lack of TCAS
- Lack of USAF RPA divert options due to launch & recovery equipment requirements

From the interviews with the USAF pilots, and from the questionnaire results, there is only a “Slight Concern” with the integration of the UAS into the NAS.

Mixed Methods

How do interviews with US Air Force UAS pilots and sensor operators help explain any quantitative differences between the most common UAS accident(s), causes and the most common safety concerns?

The questionnaire and interviews proved very beneficial in discovering whether or not there were any relationship between UAS accident causes and the common safety concerns. The quantitative research discovered that the most common reason for UAS accidents was an engine failure event, with loss of control and lost link events coming in second and third respectively. With this in mind, the question posed to the pilots queried their three greatest concerns with the integration of the UAS into the NAS, none of the pilots answered that they had a safety concern with the integration of the UAS. The seven pilots that completed the questionnaire were questioned about safety concerns with the integration of the UAS into the NAS and after collecting all the data, there was a mean concern level of 1.83 or a “Slight Concern.” The questionnaire and the interview proved that there is minimal to no concern between seven expert UAS pilots and sensor operators as it relates to the most common accidents and causes and common safety concerns.

To what extent do interviews with US Air Force UAS pilots and sensor operators help the overall understanding of safety concerns attributed with the integration of UAS into the NAS? (Content)

The questionnaire and interviews with the pilots and sensor operators shined a new perspective on concerns with the integration of the UAS into the NAS. The overall safety concern of the pilots and sensor operators was “Slight,” and when interviewed only one pilot had concern related to safety for the integration of the UAS into the NAS. The concern was not directly involving UAS safety record, but dealt with the lack of training of small UAS operators, the lack of TCAS safety equipment for USAF RPAs, which is also commonly used by US government agencies within the US, and the lack of divert options when taking off and recovering an aircraft.

Instead of safety, the other two pilots discussed concerns with public perception, misconceptions and misunderstandings of capabilities, limitations and terminology. The two pilots with these concerns discussed a misconception that an UAS cannot be safely de-conflicted from other aircraft without the use of increased airspace, lack of public and aviation community knowledge on the capabilities and limitations of an UAS and with the increase of micro-UAVs the lack of official policies governing and licensing of aircraft and pilots.

The interviews supported a negative relationship between the most common UAS accidents and causes and the most common safety concern.

CHAPTER V

# Conclusion, Recommendations, Further Research

## Summary of Research

This mixed method study was conducted to find a relationship between accidents and safety concerns related to the UAS integration into the NAS in September 2015. The study included quantitative findings from information received from the US Air Force, Army and Navy through Freedom of Information Act Requests, and the qualitative findings were gathered from UAS Pilots and Sensor Operators. Of the ten research subjects requested to participate in the study, seven took part in the online questionnaire, resulting in 70% participation, and of the seven participants, three took part in a follow-up interview, resulting in 43% participation.

## Research Objective, Questions and Findings

The relationship between UAS accidents and concerns have been completed and summarized with regards to the following research objective and questions:

Research Objective: Based on the most common UAS accidents causes and US Air Force UAS instructor and evaluator pilots and sensor operators, is there a relationship between safety concerns and safety issues?

Research Questions:

1. What safety feature prevents UAS midair collisions?
2. How many times has this safety feature prevented midair collisions?
3. What safety feature prevents accidents during lost link events?
4. How many lost link incidents have occurred ending with accidents?
5. How many lost link incidents have occurred ending without accidents?
6. What are the most common UAS accidents within the last five years?
7. Have UAS meeting airworthiness requirements been involved in more accidents than UAS not meeting airworthiness requirements?

To support the qualitative research method of the mixed method study, the following inferential questions were utilized:

1. How do current (Independent Variable 'IV') and proposed (IV) safety features integrated into a UAS prevent the most common accident (Dependent Variable 'DV') occurrences?

2. Does UAS pilot training (IV) reduce the number of UAS accidents (DV)?

The research study yielded four common accident causes from safety databases of the US Air Force, Army and Navy. The quantitative study found that the most common accidents causes for the UAS between 2009 and 2014 were pilot error, loss of control, lost link and engine failure. The qualitative study was conducted to validate if the safety concerns were related to the safety record by utilizing a questionnaire and follow-up interview of Air Force UAS Pilots and Sensor Operators. The qualitative findings showed that there was an overall slight safety concern (1.71 mean on a scale of 1-5, 1 being no concern and 5 being very concerned) with regards to the integration of the UAS into the NAS.

## Conclusions

Research Objective: Based on the most common UAS accidents causes and US Air Force UAS instructor and evaluator pilots and sensor operators, is there a relationship between safety concerns and safety issues?

Between 2009 and 2014, there were 417 reported accidents by the US Air Force (USAF), US Navy (USN) and US Army (USA) involving UAS. Of those accidents, the USAF reported 45, USA reported 324 and the USN reported 48. Of the common causes, pilot error (PE), engine failure (E), loss of control (CT), lost link (LL) and other (O), the most common accident cause was engine failure. From 2009-2014, there were at total of 145 engine failure incidents that resulted in a crash of a UAS. The Army (USA) led the field with 120 reported engine failures that resulted in a Class A, B, C or D accident. Most of the USA accidents resulted in a Class C incident (74), which made up 47% of all Class C USA accidents reported (159).

When interviewed, the top three concerns of the UAS pilots and sensor operators did not relate to the number of accidents or types of accidents, as the concerns involved policy and perception and not accident involvement:

- Tremendous growth of micro UAVs and certification process required to operate them
- Public misunderstandings of UAS capabilities
- Public capability expectations of UAS
- Overall perception that UAS cannot be safely de-conflicted from manned aircraft
- Misconception of increased airspace requirements for UAS
- Misunderstanding of naming convention of UAS in "Lost Link" event and ATC use of terms--when in a lost link event, the UAS goes into "Emergency Mission Mode" and follows way points to designated area; this does not mean the UAS is an "Emergency Aircraft."
- Lack of training for most, smaller UAS operators
- For USAF Remotely Piloted Aircraft (RPA), the lack of TCAS
- Lack of USAF RPA divert options due to launch & recovery equipment requirements

When using the Likert-Scale findings, the mixed method study showed that there was a positive relationship between the number of accidents during a specific phase of flight (takeoff & landing), and the amount of concern of those types accidents occurring. It also showed a negative relationship pertaining to the highest number of incidents and accidents occurring during a specific phase of flight (cruise) and the low number of concern with accidents occurring during that phase of flight. The calculated percentage of accidents during each specific phase of flight was categorized low to high: low- 0-29%; medium- 30-50%; high- >51%.

During the takeoff phase of flight there were a total of 84 accidents of 405 accidents that occurred during one of the three phases of flight (other phase of flight not calculated) and amounted to 21% of the number of accidents. The data observation showed that there was a positive relationship between the number of accidents and the level of concern (1.43), both low.

During the cruise phase of flight there were a total of 218 accidents of 405 total accidents that occurred during one of the three phases of flight (other phase of flight not calculated) and amounted to 54% of the number of accidents. The data observation showed that there was a negative relationship between the number of accidents and the level of concern, the number of accidents being highest and the level of concern slight (1.71).

During the landing phase of flight there were a total of 103 accidents of 405 accidents that occurred during one of the three phases of flight (other phase of flight not calculated) and amounted to 25% of the number of accidents. The data observations showed that there was a positive relationship between the number of accidents and the level of concern, the number of accidents being low and the level of concern slight (1.43).

Midair and near midair accidents and level of concern were observed, with a 15 near midair collisions and 2 midair collisions being reported. Of the 405 total accidents that were recorded, 4% could have involved a near midair incident; near midair reports were not calculated in the total number of accidents observed. Less than 1% of the accidents observed involved a midair collision. When comparing these numbers to the mean level of concern observed from the survey, there is a positive relationship between the number of incidents and accidents reported and the mean of the answers provided from three sections questioning the level of concern related to midair incidents and accidents, (1.86, 2.29, 1.50). The reported level of concern mean was 1.88, a slight concern, and the number of incidents and accidents were low.

Research Question #1: What safety feature prevents UAS midair collisions?

This study identified 15 near mid-air collisions and two mid-air collisions from 2009-2014 reported by the USN and the USA. The USN reported 15 near mid-air and zero mid-air collisions; and there were no fatalities or injuries in any of the cases reported. The USAF did not report any near mid-air or mid-air collisions. To avoid mid-air collisions, commercial airlines use a Terrain Collision Avoidance System (TCAS). Additionally, airlines use Terrain Advisory Line (TAL) to provide pilots timely information to avoid pending collisions with terrain. Currently, UAS do not have TCAS or the capability to see and avoid other aircraft. The FAA states that, “unmanned flight will require new or revised operational rules to regulate the use of SAA systems as an alternate method to comply with see and avoid operational rules,” (FAA, 2013, p. 19).

Technologically advanced UAS, utilize cameras for the operators but these cameras are only able to see a specific amount of view. To support sense or see and avoid concept, UAS aircraft and UAS pilots would have to acquire and develop a “see and avoid, radar, visual sighting, separation standards, proven technologies and procedures and well-defined pilot behaviors,” (FAA, 2013, p. 19). Currently, Ground Based Sense and Avoid (GBSAA) and Airborne Sense and Avoid (ABSAA) concepts and procedures are being studied and evaluated by public agencies and commercial companies (FAA, 2013).

Research Question #2: How many times has this safety feature prevented midair collisions?

The researcher was unable to determine the number of occurrences that the TCAS helped prevent flight into terrain or another aircraft. Additionally, because UAS lack the sense and avoid capability, this data was not able to be collected.

Research Question #3: What safety feature prevents accidents during lost link events?

The Lost link safety feature is programmed to direct the UAS to waypoints in route to its home station if it loses link to its host. It was determined there were 71 total lost link occurrences reported from the USAF, USN, and USA.

Research Question #4: How many lost link incidents have occurred ending with accidents?

The study found there were 71 lost link incidents between the USAF, USA and USN, All 71 of the reported lost link incidents resulted in terrain or crash landings.

Research Question #5: How many lost link incidents have occurred ending without accidents?

Of the 71 lost link incidents between the USAF, USA and USN, all 71 of the reported lost link incidents resulted in terrain or crash landings.

Research Question #6: What are the most common UAS accidents within the last five years?

The most common UAS accidents identified in this study were attributed to pilot error, engine failure, loss of control, lost link and other causes (weather, electrical, runway overrun, etc.). Of these common causes, the most common accident cause was engine failure. From 2009-2014, there were at total of 145 engine failure incidents that resulted in a crash of a UAS.

Research Question #7: Have UAS meeting airworthiness requirements been involved in more accidents than UAS not meeting airworthiness requirements?

Military UAS were studied for this research study and all military UAS meet strict airworthiness standards set by the Department of Defense. For operations of UAS within the US NAS, a UAS will receive airspace access through issuance of Certificate of Waiver or Authorization and through receipt of a special airworthiness certificates.

The FAA Roadmap (2013) elaborates that "to gain full access to the NAS, UAS need to be able to bridge the gap from existing systems requiring accommodations to future systems that are able to obtain a standard airworthiness certificate (FAA, 2013, p. 6)."

Inferential Question #1: How do current (Independent Variable 'IV') and proposed (IV) safety features integrated into a UAS prevent the most common accident (Dependent Variable 'DV') occurrences?

The RQ-1 was identified as the UAS to study for safety features based on its technological capabilities. The systems that support the RQ-1 flight operations and act as current safety features (IV) include an "inertial navigation system, satellite communications, Identification Friend or Foe (IFF) transponder, primary & secondary control modules, electro-optical infrared sensor and synthetic aperture RADAR (SAR)," (Valdes, 2015, p. 2). The IFF allows for flight following (IV), the satellite communications allows beyond-line-of-sight control of the aircraft (IV), the optical cameras (IV) ensure the pilot can see in front of and to the side of the aircraft during day and night time operations and the SAR (IV) supports terrain mapping.

It was found that the equipment do not make up for a pilot actually being inside the aircraft. The camera utilized by the RQ-1 has viewing limits and this sight limitation adds to the See and Avoid (SAA)/ (IV) safety issue. In addition, the RQ-1 does not carry a Terrain Collision and Avoidance System (TCAS)/ (IV). Without TCAS the UAS pilot manned piloted aircraft within the NAS are unable to know they are on a collision course.

During the interview of the research subjects, "the lack of TCAS (IV)," was acknowledged as a safety concern.

Inferential Question #2: Does UAS pilot training (IV) reduce the number of UAS accidents (DV)?

The FAA Roadmap (2013) highlights the importance of training to help increase safety. The Roadmap (2013) emphasizes the importance of pilot training but also continues to require training for flight crewmembers, mechanics and air traffic controllers, "UAS training standards will mirror manned aircraft training standards to the maximum extent possible," (FAA, 2013, p. 28). Research Subject #3, "the second most important issue is training (IV); there is a misconception that less training is required to pilot an RPA. I can tell you from experience that is not the case due to the reduced situational awareness (SA) and inherent delay in the RPA operations."

Research Subject #3 describes that one of the greatest concerns for the integration of the UAS in the NAS is “lack of training for most, smaller UAS operators.” Research Subject #3 stated that “this is not the time to develop UAS ‘sport pilot’ equivalent certificate for any civilian operated quad-copter or smaller platform…but due to system limitations inherent to most UAS, including reduced ability to sense and avoid, solid training and procedures are required to safely integrate within the NAS.” Research Subject #2 stated that to rectify concerns would be to “educate the aviation community as a whole about UAS operations, in particular education should focus on capabilities and limitations of the RPA and about the training the pilot receives.” Research Subject #2 continued to state, “the FAA/ATC can take many lessons on RPA incorporation with manned aircraft and operations in the NAS from the military. Specifically, they can model civilian operations after the operations from major operating airfields and airspaces in combat areas.” Research Subject #2 and #3 acknowledged that educating and training pilots is essential in the safe operations of the UAS in the NAS, and training policies set by the FAA should mandate these training requirements that build on experience and knowledge.

## Recommendation

### Recommendation #1

The FAA has crafted FAA Roadmap 2013 and implemented the UAS Integration Office to support the integration and operations of UAS. The FAA should continue to refine the Roadmap (2013) as the integration process begins and update policy and regulations as required. The UAS Integration Office should provide UAS operators a way to provide feedback and lessons learned to make the process, procedures and operations of the UAS safer and efficient. Additionally, the FAA should research ways to deal with and implement contingency plans for unintentional and deliberate accidents involving UAS and further legislation must budget for the increased requirements.

Recommendation #2

The FAA Roadmap 2013 stresses the importance of training pilots, crews, maintenance and air traffic controllers on UAS operations and this should continue and evolve as the integration progresses. The training provided should be monitored and reviewed by Flight Standard District Office (FSDO) Inspectors and held to the same standards as manned aircraft and pilots. The FAA must create and uphold a standards and evaluations system that mirrors manned flight operations but is also unique to UAS flight operations. FSDO Inspectors should provide inputs into the success and failures of such a system as they gather information from field inspections.

Recommendation #3

The public perception of the UAS is garnered from what is seen on the news and this may skew the views on operations and safety of the UAS. The public may not have a good understanding of the capabilities and limitations of the UAS as well as the background and concept of the FAA Modernization and Reform Act 2012. Research Subject #1 and #2 stated that their concerns included, "public misunderstandings of UAS capabilities, public capability expectations of UAS, overall perception that UAS cannot be safely de-conflicted from manned aircraft and misconception of increased airspace requirements for UAS." The UAS Integration Office should research and implement a public service campaign to inform the public of UAS operations, the concept of the Reform Act and way forward for the safe integration of the UAS into NAS. This campaign's focus should aim to inform the public of UAS operations and change a negative perception of UAS use and safety issues. The UAS Integration Office must implement a way to track safety issues, such as accidents, near mid-air and mid-air collisions as well as any research done on UAS operations and provide public accessibility to this database for review.

## Recommendation for Further Research

Due to the small sample size utilized for this research study, further research must be accomplished to ensure that all avenues of the safe integration of the UAS into the NAS have been covered. For this research study only US Air Force UAS Pilots and Sensor Operators were utilized for as research subjects. Of the requested ten research subjects only seven UAS Pilots and Sensor Operators were utilized to complete the questionnaire, and of those only three conducted a follow-up interview. Future research conducted should include a sample size conducive to the general public and non-military UAS pilots.

The FAA should take steps to implement databases that track UAS operations and safety issues with regard to the UAS operations within the NAS. This database should be utilized for comparison and analysis for future research projects, as outlined in the FAA Roadmap 2013, and findings should drive regulation and legislative updates. Future research should include and be directed towards the current regulations and legislation and discover if the status quo is sufficient for the safe integration of the UAS into the NAS, and if not, why and what needs to change to ensure the safe operations of the UAS in the NAS.

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# APPENDICES

# APPENDIX A

# SAFETY CONCERN QUESTIONNAIRE

LEVEL OF KNOWLEDGE AND UNDERSTANDING:

*Knowledge: Familiarity with system to include facts, information, or skills*

*Understanding: Knowledge sufficient to support intelligent behavior with respect to an objects abilities and disposition*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| None | Some | Well | Very | Expert |

1 – None

2 – Some

3 – Well

4 – Very Well

5 – Expert

**On a scale of 1 - 5, please rate your knowledge of:**

Unmanned aerial systems (UAS) capabilities.

1 2 3 4 5

Civilian aircraft safety features requirements?

1 2 3 4 5

UAS aircraft safety features requirements?

1 2 3 4 5

Understanding operations of aircraft safety features?

1 2 3 4 5

Different UAS missions?

1 2 3 4 5

Understanding of the different UAS missions?

1 2 3 4 5

The National Airspace System (NAS)?

1 2 3 4 5

Understanding of the NAS requirements for flight operations?

1 2 3 4 5

SAFETY:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Not Concerned | Slightly Concerned | Moderately Concerned | Very Concerned | Extremely Concerned |

1 – Not at all concerned

2 – Slightly concerned

3 – Moderately concerned

4 – Very concerned

5 – Extremely concerned

**On a scale of 1 - 5 with regards to standard manned flight, please rate your level of concern as it pertains to:**

Belief that flying within the domestic United States is not safe?

1 2 3 4 5

Domestic airliner's safety record when you are flying in a commercial airliner?

1 2 3 4 5

Oversaturation of the NAS with airplanes day to day?

1 2 3 4 5

Mid air collisions when you fly?

1 2 3 4 5

Runway incursions when you fly?

1 2 3 4 5

Being involved in an aircraft accident during takeoff?

1 2 3 4 5

Being involved in an aircraft accident at cruise altitude?

1 2 3 4 5

Being involved in an aircraft accident during landing?

1 2 3 4 5

**Based on an increase of UAS in the NAS, on a level of 1 - 5 how concerned are you:**

Being involved in an aircraft accident with a UAS during takeoff?

1 2 3 4 5

Being involved in an aircraft accident with a UAS during cruise?

1 2 3 4 5

Being involved in an aircraft accident with a UAS during landing?

1 2 3 4 5

If you knew that a UAS had less safety equipment than commercial airliners, how concerned would you be for airspace safety?

1 2 3 4 5

Based on your understanding and knowledge of UASs, how concerned are you that an accident would occur if a UAS lost its data connection to the operator?

1 2 3 4 5

How concerned are you that UAS in the national airspace system would cause more mid air collisions?

1 2 3 4 5

How concerned are you that the UAS in the national airspace system would increase the potential of accidents with terrain (i.e. homes, buildings, roads, populated areas)?

1 2 3 4 5

There will be an increase in aircraft accidents with a UAS during takeoff?

1 2 3 4 5

There will be increases in aircraft accidents with a UAS during cruise?

1 2 3 4 5

An increase in aircraft accidents with a UAS during landing?

1 2 3 4 5

Based on your knowledge of UASs safety features, how concerned would you be for airspace safety?

1 2 3 4 5

Based on your knowledge of UASs, how concerned are you that an accident would occur if a UAS lost its data connection to the operator?

1 2 3 4 5

How concerned are you that UAS in the national airspace system would cause more mid air collisions?

1 2 3 4 5

How concerned are you that the UAS in the national airspace system would increase the potential of accidents with terrain (i.e. homes, buildings, roads, populated areas)?

1 2 3 4 5

<u>DEMOGRAPHICS:</u>

Age: 20-29 30-39 40-49 50-54

Race: Caucasian African American Hispanic Asian Other

Education (level completed): High School Associate Bachelor Masters Doctorate

Number of commercial flights (approximate): None 1-9 10-19 20+

# APPENDIX B

# FOLLOW ON INTERVIEW QUESTIONS

Briefly describe your aviation experience to include training, flight hours, pilot or aircrew experience.

Briefly describe your experience and knowledge of unmanned aerial systems to include any piloting or sensor operator experience or any research you've accomplished.

Briefly describe your duties in the current position you hold to include training, years of experience and daily duties.

Describe your experience conducting safety inspections, mishap investigations and/or accident investigations.

Based on your answers to the unmanned aerial system (UAS) safety questionnaire, describe in your professional opinion the top three greatest concerns you have with the integration of the UAS in the National Airspace System (NAS).

Based on your answers to your greatest concerns of the UAS integration into the NAS, what needs to be done to rectify those top three concerns?

In your overall assessment, do you feel the integration of the UAS into the NAS is a major safety concern or do you feel that with the current direction of the integration there will be minimal impact to safety?

APPENDIX C

FREEDOM OF INFORMATION ACT REQUESTS

# FREEDOM OF INFORMATION (FOIA) Request

<table>
<tr><td>RECORDS RELEASE OFFICE<br>DEPARTMENT OF THE ARMY<br>OFFICE OF THE INSPECTOR GENERAL<br>1700 ARMY PENTAGON<br>ATTN: SAIG-ZXR ROOM 1E132<br>WASHINGTON, DC 20310-1700<br><br>PHONE (703) 545-4591 FAX (703) 545-4585<br>DSN 865-4591 DSN 865-4585</td><td>REQUESTER'S NAME AND ADDRESS:<br><br>Omar J. Hamilton<br>PSC 78 Box 3337<br>APO, AP 96326</td></tr>
<tr><td></td><td>TELEPHONE NO: 623-734-9664</td></tr>
<tr><td>DATE OF REQUEST: 5 Sept 2014</td><td>E-MAIL ADDRESS: omar.hamilton@okstate.edu</td></tr>
</table>

**This is a request under the Freedom of Information Act (5 USC 552)**

**I request a copy of the following document(s). (Give a brief description of the requested record of information. Provide the IG Case Number and/or the IG Inspection Report's Subject Matter, if known).**

I am inquiring about assistance for gathering Army UAS accident/incident/mishap information to support the completion of my dissertation for my Doctor of Education degree.

The dissertation is titled "The Integration of the Unmanned Aerial System in the National Airspace System; Correlation Between Safety Record and Safety Concerns." Part of my dissertation is to collect in a quantitative manner the number of accidents and causes for UAS over the last 5 years.

I request that the information pertaining to mishap/accident include: year of accident, UAS Model, location of accident (if releasable), cause of accident/incident/mishap (i.e. lost link, weather, etc.) AND/OR type of accident/incident/mishap (i.e. crash during takeoff, flight into terrain, etc.) any injuries/deaths or destruction to personal property and accident Class. I understand that some of the information is not releasable, so any information I may be able to receive would be appreciated. I am collecting the data for my report from military operators and civilian operators.

If possible, I request access to a public database or a report with the applicable information between Jun 2009-Jun 2014 to support my research. If you have any questions or concerns, please contact me at the email provided or via phone at the number below. Thank you for your time with this matter.

○ **I am seeking information for personal use.**

○ **I am representative of the news media affiliated with the newspaper, magazine, television station, etc. This is request is made as part of news gathering and is not for commercial use.**

● **I am affiliated with educational or non-commercial scientific institution. This request is made for scholarly or scientific purpose and not for commercial use.**

○ **I am affiliated with a private business. I am seeking information for the company.**

○ **I am willing to pay fees to the maximum of $_____________. If you estimate that the fees will exceed this limit, please inform me.**

● **I am asking for a fee waiver (justification):**

The information gathered is for research purposes and may be beneficial to aviation safety and regulation improvements for the integration of unmanned aerial systems into the national airspace system in 2015.

○ **I am requesting Expedited Processing (justification):**

____________________________________________________________

____________________________________________________________

____________________________________________________________

○ **This request is on behalf of________________________________. Attached is the written consent from the individual concerned.**

________________________

**Signature**

**DAIG FOIA REQUEST FORM, February 2011 (DAIG-ZXL)**

DEPARTMENT OF THE NAVY
NAVAL SAFETY CENTER
375 A STREET
NORFOLK, VA 23511-4399

5720
Ser 023/F0123
August 20, 2014

Major Omar Hamilton, USAF
PSC 78, Box 3337
APO AP 96326

Dear Major Hamilton:

SUBJ: YOUR FREEDOM OF INFORMATION ACT CASE 2014-NSC-115; DON-NAVY-2014-008177

This is in response to your Freedom of Information Act (FOIA) request of July 29, 2014 requesting data on Navy UAS mishaps. Specifically, you asked for the UAS model, location of the mishap (if releasable), cause and type of mishap, injuries/deaths, damage to property and classification of mishap.

Enclosed is a redacted copy of an Excel spreadsheet which meets the criteria of your request. This redacted copy includes the factual information contained in the original spreadsheet and excludes the locations of events classified as Class A through C mishaps. Causal factors are privileged and, because some of the short narratives reveal what the causal factors may have been, I have removed the locations to mask the specific mishap. Since hazard reports (identified in Column D (EVENT_SEVTY) as "H") are not privileged, no information has been redacted from those rows of data.

Because your request has been partially denied, you have the right to appeal this determination in writing to the designee of the Secretary of the Navy under the above statute. Your appeal, if any, must be addressed to:

Judge Advocate General (Code 14)
Navy Department
Washington Navy Yard
1322 Patterson Ave., S.E.
Suite 3000
Washington, DC 20374-5066

The appeal must be postmarked within 60 days from the date of this letter. A copy of your initial request and this partial denial letter must accompany the appeal. The appeal should be marked "FREEDOM OF INFORMATION ACT APPEAL" both on the envelope and the face of the letter. In order to expedite the appellate process and ensure full consideration of your request, your appeal should contain a brief statement of the reasons you believe this initial decision to be in error. The official responsible for the partial denial of your request is:

Kenneth J. Norton
Rear Admiral, U.S. Navy
Commander, Naval Safety Center

Your request was treated as an "all others requester" as defined by Secretary of the Navy Instruction 5720.42F dated 6 January 1999, Subject: DEPARTMENT OF THE NAVY FREEDOM OF INFORMATION ACT (FOIA) PROGRAM. There are no fees associated with the processing of your request in this instance.

If you have any questions, you may contact Mr. James Webb at (757) 444-3520 Ext 7096 or via e-mail at safe-foia@navy.mil. Please refer to case number 2014-NSC-115 when inquiring about your request.

Sincerely,

N. B. JONES
Staff Attorney
By direction of the Commander

Enclosure

APPENDIX D

US AIR FORCE ACCIDENT DATABASE

| Year | LOC | CLASS | MODEL | EVENT_SHORT_NARR |
|---|---|---|---|---|
| 2009 | W | A | MQ1B | Electrical failure of primary control module (PCM) |
| 2009 | U | A | MQ1B | Engine failure due to improper oil sys temp valve assembly |
| 2009 | W | | MQ1B | Electrical failure-lost link crash |
| 2009 | U | A | MQ1B | Loss of manifold absolute pressure (MAP) on takeoff, loss of engine power; vacuum line disconnect |
| 2009 | W | A | MQ1B | Loss of controlled flight due to dislodged software chip |
| 2009 | W | | MQ1B | Lost link |
| 2009 | W | A | MQ1B | Quill shaft failure due to manufacturer improper tempering |
| 2009 | W | A | MQ1B | Mechanical failure of variable pitch propeller (VPP) servo |
| 2009 | W | | MQ1B | Loss of servo control & subsequent lost link |
| 2009 | W | A | MQ1B | Electrical failure, lost link & emergency procedure inability |
| 2009 | W | A | MQ1B | Controlled flight into terrain mountain; pilot error |
| 2010 | W | A | MQ1B | Oil leak leading to engine failure |
| 2010 | U | | MQ9 | Unknown |
| 2010 | W | A | MQ1B | Pilot error during T/O |
| 2010 | U | | MQ1B | Pilot error during taxi |
| 2010 | U | A | MQ1B | Pilot error during touch and go |
| 2010 | W | | MQ1B | Unknown |
| 2010 | W | A | MQ1B | Pilot error during stall recovery |
| 2011 | W | A | EQ4 | Electrical power interruption to aerilon/spoiler controls |
| 2011 | W | A | MQ1B | Quill shaft failure |
| 2011 | W | A | MQ1B | Lost link - no wreckage found |
| 2011 | W | A | MQ1B | Lost link - flew into weather |
| 2011 | W | A | MQ1B | Lost link - lightning strike |
| 2011 | W | A | MQ1B | Pilot error - Impact w/ground during landing |
| 2011 | U | A | QRF-4C | Electrical power disruption & pilot error |
| 2011 | W | A | MQ1B | Loss of electrical power to aileron |
| 2011 | W | A | MQ1B | Engine failure; Pilot error during recovery (hit fence) |
| 2011 | W | A | MQ1B | Prop thrust bearing failure (engine) |
| 2011 | W | | MQ1B | Runway overrun (hit fence) |
| 2011 | W | A | MQ1B | Engine failure due to loss of oil |
| 2011 | W | A | MQ1B | Lost link |
| 2011 | N | A | MQ9A | Pilot error - Forced landing; uncommanded engine shutdown |
| 2012 | W | A | MQ1B | Lost link |
| 2012 | W | A | MQ1B | Lost link |
| 2012 | W | A | MQ1B | Crew error - crash during T/O, uncommanded roll |
| 2012 | W | A | MQ1B | Engine failure |
| 2012 | N | A | MQ9A | Pilot error - fuel flow shut off |
| 2012 | W | A | MQ1B | Engine failure - Hard ditch |
| 2012 | W | A | MQ1B | Forced landing - engine coolant leak |
| 2012 | W | A | MQ1B | Dual alternator failure - damage to farmhouse & crops |

| | | | | |
|---|---|---|---|---|
| 2012 | W | A | MQ1B | VPP failure - checklist discipline (pilot error) |
| 2012 | U | A | MQ9A | Pilot error |
| 2013 | W | A | MQ1B | Lack of thrust & increased wind during T/O |
| 2013 | U | A | MQ1B | VPP failure |
| 2013 | W | A | MQ1B | Memory chip failure leading to uncommanded movements |

# APPENDIX E

# US NAVY ACCIDENT DATABASE

| EVENT_SEVTY_C | ACFT_MODEL | EVENT_SHORT_NARR |
|---|---|---|
| A | MQ008B | MQ-8 failed to acquire automated recovery system, ran out of fuel and impacted water |
| A | MQ008B | MQ-8 made an uncommanded Navigator mode change out of normal mode of operation resulting in a crash |
| A | RQ004A | UAV Class A Flight Mishap with ruddervator malfunction. No injuries or fatalities. |
| A | MQ008B | Loss of MQ-8B during recovery |
| A | K-MAX | Cargo Resupply Unmanned Aerial Vehicle (CRUAS/K-MAX) flight mishap. |
| A | MQ008B | MQ-8B experienced a hard landing from a hover just after takeoff |
| A | BQM74 | BQM-74E Target impacted US Navy Ship during Combat Systems Ship Qualification Trials. |
| A | MQ008B | MQ-8B crashed at sea. |
| B | RQ007B | RQ-7B SHADOW EXPERIENCED ENGINE CUT ON TAKEOFF AND IMPACTED GROUND. |
| B | RQ007B | Shadow UAV lost link and impacted the ground |
| B | MQ008B | MQ-8B Fire Scout sustained damage in flight. |
| B | RQ021A | RQ-21: During test flight for new recovery zone, contractor-operated RQ-21 crashed on short final |
| B | RQ021A | UAS engine failed to cut off on recovery and A/C swung into recovery hook. |
| C | SCANEAGL | SHORTLY AFTER TAKEOFF UAV LOST POWER AND IMPACTED WATER. |
| C | RQ007B | UAV INTENTIONALLY DEPLOYED PARACHUTE AFTER BEING UNABLE TO LAND. NO INJ |
| C | RQ007B | ACFT LANDED ON RNWY EDGE AND COLLIDED WITH SHADOW ARRESTING GEAR EQPT |
| C | RQ007B | SHADOW UAV IMPACTED GROUND SHORT OF RUNWAY DUE TO ENGINE PROBLEMS. |
| C | RQ007B | UNMANNED ACFT ENG SHUT DOWN IN FLIGHT, NO INJURIES. ACFT WAS RECOVERED |
| C | RQ007B | UNMANNED ACFT ENG SHUT DOWN IN FLIGHT. NO INJURIES. ACFT WAS RECOVERED |
| C | RQ007B | UAV impacted ground under a deployed parachute after experiencing an engine failure on a FAM flight. |
| C | RQ007B | (b)(5) RQ-7B Propulsion System Failure |
| C | RQ007B | UAV LAUNCHED, FLEW PAST FIELD BOUNDARIES TO AN ALTITUDE OF 250' AGL, ENGINE STOPPED, CRASHED. |

| | | |
|---|---|---|
| C | RQ007B | RQ-7B ENGINE FAILED DURING RECONNAISSANCE MISSION. AIRCRAFT LANDED UNDER RECOVERY PARACHUTE. |
| C | RQ007B | RQ-7B engine failure after departure from LZ (b)(5) |
| C | MQ008B | MQ-8B hot start during ground turn. |
| C | SCANEAGL | ScanEagle CFIT |
| C | RQ007B | An IE RQ-7B Shadow experienced engine failure resulting in FTS deploy. |
| C | SCANEAGL | ScanEagle departure from controlled flight during recovery phase. |
| H | MQ009 | Due to lost link, MQ-9 strayed outside of restricted operating area |
| H | MQ009 | During handover training aircraft engine was inadvertently secured |
| H | MQ009 | INFLIGHT GENERATOR FAILURE |
| H | RQ002B | UNINTENTIONAL ENGINE CUT DURING FINAL APPROACH |
| H | RQ007B | RQ-7B SHADOW UAV EXPERIENCED A LEFT ELERUDDER SERVO FAILURE |
| H | RQ007B | RQ-7B Shadow UAV hard landing |
| H | SCANEAGL | SCAN EAGLE UAV ENGINE FAILURE LEADS TO EMERGENCY LANDING |
| H | RQ007B | Upon normal UAV Tactical Automated Landing System recovery one of the arresting gear straps broke |
| H | RQ007B | ACE II Box Warm Boot immediately after launch causes near mishap. |
| H | RQ001 | ***Three near mid-air events with UAV's in 2 week span. |
| H | SCANEAGL | ***Scan Eagle taking off from 05L crossed 100' in front of AH-1W on GCA final to 23L. |
| H | RQ007B | RQ-7B was cleared to RTB with procedural control while another UAV was in its path coaltitude |
| H | RQ007B | RQ-7B RPA was descending to intercept final and experienced engine stoppage due to fuel starvation |
| H | RQ007B | RQ-7B in landing phase experienced fuel starvation and deployed parachute |
| H | RQ021A | RQ-21A GPS signal failure results in STUAS emergency landing |
| H | RQ007B | RQ-7B landed, caught arresting gear, gear snapped, Air Vehicle experienced net arrestment. |
| H | MQ001L | ***Near Mid-Air Collision with RPA on IFR Departure |
| H | RQ007B | RQ-7B experienced engine emergency and decided to RTB. Engine failed close to base and crashed |
| H | RQ007B | RQ-7B experienced sudden engine failure in flight with no indication. Deployed parachute. |
| H | RQ007B | RQ-7B experienced engine failure in flight during OEF mission. AV was recovered. |
| H | RQ021A | RQ-21A (STUAS) crashed during recovery at Twenty-Nine Palms |
| H | MQ001L | ***P-3 Near mid-air collision during tactical event |
| H | MQ001L | ***P-3 Uncommanded climb of UAV causes potential near mid-air. |

| | | |
|---|---|---|
| H | SCANEAGL | Scan Eagle experiences airspeed sensor failure resulting in a water landing. |
| H | RQ004A | ***A BAMS-D RQ-4A was struck by a Bird while within the Class D airspace of NAS Patuxent River (KNHK). |
| H | RQ004A | RQ-4A aileron actuator malfunction during descent for arrival. |
| H | MQ009 | ***P-3 Near Mid-Air Collision During Operational Mission |
| H | RQ007B | An RQ-7B Shadow was damaged during recovery. |
| H | UNKNOWN | ***NEAR MID-AIR WITH UNKNOWN AIRCRAFT |
| H | RQ007B | An RQ-7B had a TFOA incident on a routine training flight in the R-2301W airspace. |
| H | UNKNOWN | ***AIRCRAFT NEAR MID-AIR COLLISION WITH A REMOTELY PILOTED AIRCRAFT |
| H | RQ23A | RQ-23A TigerShark Block IIIA UAV stalled shortly after take-off |
| H | UNKNOWN | ***Air Traffic Controller authorized a UAV to taxi onto a runway occupied by a vehicle |
| H | RQ004A | ***RQ-4: Navy RQ-4A and Air Force RQ-4B Near Mid Air Collision |
| H | UNKNOWN | ***NEAR MID-AIR COLLISION |
| H | MQ009 | ***Crew Experiences two near mid-air events with RPAs |
| H | MQ009 | ***Bird strike to a NASA Ikhana UAV at PMRF Barking Sands. |

***Numbers did not count towards accident numbers (17 incidents)

***Near midair incidents counted separately

APPENDIX F

US ARMY ACCIDENT DATABASE

| Crash Type | CLASS | MODEL | EVENT_SHORT_NARR |
|---|---|---|---|
| Forced Landing/UAS FTS Employed | A | MQ-5B | Fuel Starvation |
| Spin/Stall | A | MQ-5B | Contractor Aircraft Accident |
| Engine Failure | A | MQ-5B | Contractor Aircraft Accident |
| Contractor Aircraft Accident | A | MQ-1C | Avionics |
| Spin/Stall | A | MQ-5B | Contractor Aircraft Accident |
|  | A | MQ-1B | Collision With Ground/Water |
| Collision With Ground/Water | A | MQ-5B | Contractor Aircraft Accident |
| Forced Landing/UAS Fts Employed | A | YMQ-18A | Fuel Starvation |
|  | A | MQ-1B | Collision With Ground/Water |
|  | A | MQ-5B | Collision With Ground/Water |
|  | A | MQ-5B | Other Collision |
|  | A | MQ-5B | Collision With Ground/Water |
| Avionics | A | MQ-5B | Contractor Aircraft Accident |
| Uncommand Control Input | A | MQ-1C | Contractor Aircraft Accident |
| Other Collision | A | RQ-7B | Multiple Aircraft Event |
| Other Collision | A | MQ-1B | Engine Over speed/Overtemp |
|  | A | MQ-5B | Other Collision |
| Other Collision | A | MQ-1B | Engine Over speed/Overtemp |
| Other Collision | A | MQ-1C | Power Train |
|  | A | MQ-1C | Other Collision |
| Other Collision | A | MQ-1C | Landing Gear Collapse/Retraction |
| Undershoot | A | MQ-1C | Engine Failure |
| Engine Failure | A | MQ-1C | Engine Over speed/Overtemp |
| Other Collision | A | MQ-1C | Engine Failure |
| Other Collision | A | MQ-5B | Engine Failure |
|  | A | MQ-5B | Other Collision |
|  | A | MQ-1C |  |
|  | A | MQ-1B | Other Collision |
| Collision With Ground/Water | A | MQ-1C | Engine Failure |
|  | A | MQ-1C | Other Collision |
|  | A | MQ-5B | Collision With Ground/Water |
|  | A | MQ-1C | Other Collision |
|  | A | MQ-1C | Collision With Ground/Water |
|  | A | MQ-1B | Collision With Ground/Water |
|  | A | MQ-1B | Engine Failure |
| Collision With Ground/Water | A | MQ-1C | Uncommand Control Input |
| Collision With Ground/Water | B | RQ-7B | Engine Over speed/Overtemp |
| Engine Failure | B | RQ-7B | Electrical System |
| Electrical System | B | RQ-7B | Engine Failure |
| Collision With Ground/Water | B | RQ-7B | Engine Failure |

| | | | |
|---|---|---|---|
| | B | RQ-7B | Collision With Ground/Water |
| | B | RQ-7B | Electrical System |
| | B | RQ-7B | Overshoot/Overrun |
| Tree Strike | B | RQ-7B | Engine Failure |
| | B | RQ-7B | Engine Failure |
| Drive Train | B | RQ-7B | Engine Failure |
| Aborted Takeoff | B | MQ-5B | Contractor Aircraft Accident |
| Forced Landing/UAS Fts Employed | B | RQ-7B | Engine Failure |
| Fuel Starvation | B | RQ-7B | Electrical System |
| Engine Failure | B | RQ-7A | Fts Parachute Failure |
| | B | RQ-7B | Electrical System |
| Ground Loop/Swerve | B | MQ-5B | Aborted Takeoff |
| Other Collision | B | RQ-7B | Contractor Aircraft Accident |
| Power Train | B | RQ-7B | Forced Landing/UAS Fts Employed |
| Electrical System | B | RQ-7B | Missing Aircraft/UAS |
| Electrical System | B | RQ-7B | Engine Failure |
| Engine Failure | B | RQ-7B | Engine Over speed/Overtemp |
| Missing Aircraft/UAS | B | RQ-7B | Engine Failure |
| Other Collision | B | RQ-7B | Engine Failure |
| | B | RQ-7B | Object Strike |
| Forced Landing/UAS Fts Employed | B | RQ-7B | Engine Failure |
| | B | RQ-7B | Collision With Ground/Water |
| | B | RQ-7B | Engine Failure |
| | B | RQ-7B | Other Collision |
| Object Strike | B | RQ-7B | Engine Failure |
| Other Collision | B | RQ-7B | Engine Over speed/Overtemp |
| Collision With Ground/Water | B | RQ-7B | Fuel Starvation |
| | B | RQ-7B | Collision With Ground/Water |
| Uncommand Control Input | B | RQ-7B | Engine Over torque/Overload |
| Other Collision | B | RQ-7B | Flight Control |
| Forced Landing/UAS FTS Employed | B | RQ-7B | Flight Control |
| Forced Landing/UAS FTS Employed | B | RQ-7B | Avionics |
| Collision With Ground/Water | B | RQ-7B | Electrical System |
| Other Collision | B | RQ-7B | Engine Failure |
| Overshoot/Overrun | B | RQ-7B | Hard Landing |
| Forced Landing/UAS FTS Employed | B | RQ-7B | Fuel System |
| Other Collision | B | RQ-7B | Electrical System |
| | B | RQ-7B | Collision With Ground/Water |
| Forced Landing/UAS FTS Employed | B | RQ-7B | Engine Over speed/Overtemp |
| Forced Landing/UAS FTS Employed | B | RQ-7B | Engine Over speed/Overtemp |
| Object Strike | B | RQ-7B | Tactical Automated Landing System (TALS) |
| | B | RQ-7B | Collision With Ground/Water |
| IMC Related | B | RQ-7B | Flight Control |

| | | | |
|---|---|---|---|
| Forced Landing/UAS FTS Employed | B | RQ-7B | Engine Failure |
| Other Collision | B | RQ-7B | Engine Failure |
| | B | RQ-7B | Other Collision |
| Other Collision | B | RQ-7B | Uncommand Control Input |
| | B | RQ-7B | Collision With Ground/Water |
| Other Collision | B | RQ-7B | Electrical System |
| | B | RQ-7B | Collision With Ground/Water |
| Aircraft Collision On The Ground | B | MQ-1C | Multiple Aircraft Event |
| | B | RQ-7B | Missing Aircraft/UAS |
| | B | MQ-1C | Fuel Exhaustion |
| | B | RQ-7B | Other Collision |
| | B | RQ-7B | Other Collision |
| | B | RQ-7B | Other Collision |
| | B | RQ-7B | |
| | B | RQ-7B | Collision With Ground/Water |
| | B | RQ-7B | |
| | B | RQ-7B | Other Collision |
| | B | RQ-7B | Missing Aircraft/UAS |
| | B | RQ-7B | Collision With Ground/Water |
| | B | RQ-7B | Collision With Ground/Water |
| | B | MQ-5B | |
| Engine Failure | B | RQ-7B | Collision With Ground/Water |
| | B | RQ-7B | |
| | B | RQ-7B | Engine Failure |
| | B | RQ-7B | |
| | C | RQ-11B | Collision With Ground/Water |
| | C | MAV | Collision With Ground/Water |
| Engine Failure | C | RQ-7B | Electrical System |
| Collision With Ground/Water | C | RQ-11B | Avionics |
| | C | RQ-7B | Object Strike |
| Collision With Ground/Water | C | RQ-7B | FTS Parachute Failure |
| Flight Control | C | RQ-11B | Collision With Ground/Water |
| | C | RQ-7B | Engine Over speed/Overtemp |
| Engine Failure | C | RQ-7B | Forced Landing/UAS Fts Employed |
| Avionics | C | RQ-11B | Missing Aircraft/UAS |
| | C | RQ-11B | Collision With Ground/Water |
| | C | RQ-7B | Collision With Ground/Water |
| | C | RQ-7B | Engine Failure |
| Forced Landing/UAS Fts Employed | C | MAV | Electrical System |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| | C | RQ-7B | Engine Over speed/Overtemp |
| | C | RQ-7B | Forced Landing/UAS Fts Employed |

| | | | |
|---|---|---|---|
| Engine Over speed/Overtemp | C | RQ-7B | Engine Failure |
| Engine Over speed/Overtemp | C | MQ-5B | Forced Landing/UAS Fts Employed |
| Engine Failure | C | MQ-5B | Forced Landing/UAS Fts Employed |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| Missing Aircraft/UAS | C | RQ-11A | Collision With Ground/Water |
| Undershoot | C | RQ-7B | Electrical System |
| | C | RQ-7B | |
| | C | RQ-7B | Collision With Ground/Water |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Flight Control |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| | C | RQ-7B | Electrical System |
| | C | RQ-7B | Electrical System |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| Collision With Ground/Water | C | RQ-7B | Airframe |
| | C | RQ-7B | Collision With Ground/Water |
| Engine Failure | C | RQ-7B | Forced Landing/UAS Fts Employed |
| Collision With Ground/Water | C | RQ-7B | Launcher Malfunction |
| Object Strike | C | MQ-1C | |
| | C | RQ-7B | Engine Failure |
| | C | RQ-7B | Engine Failure |
| Tree Strike | C | RQ-7B | Flight Control |
| | C | RQ-7B | Collision With Ground/Water |
| Other Collision | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Over speed/Overtemp |
| Collision With Ground/Water | C | RQ-7B | Engine Failure |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Fuel Starvation |
| Collision With Ground/Water | C | MAV | Fuel Exhaustion |
| Collision With Ground/Water | C | RQ-7B | Engine Failure |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| | C | RQ-7B | Electrical System |
| | C | RQ-7B | Other Collision |
| Other Collision | C | RQ-7B | Undershoot |
| Other Collision | C | MAV | Engine Failure |
| | C | RQ-7B | Fire And/or Explosion On The Ground |
| | C | RQ-7B | |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Engine Over speed/Overtemp |
| Other Collision | C | MQ-5B | Overshoot/Overrun |
| Other Collision | C | RQ-7B | Uncommand Control Input |
| | C | MQ-1C | Other Collision |
| Other Collision | C | RQ-7B | Engine Over speed/Overtemp |
| | C | MAV | Collision With Ground/Water |
| Other Collision | C | RQ-7B | Engine Failure |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Fuel Starvation |

| | | | |
|---|---|---|---|
| Other Collision | C | RQ-7B | Uncommand Control Input |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Tactical Automated Landing System (TALS) |
| Engine Failure | C | RQ-7B | Engine Over speed/Overtemp |
| | C | PUMA | Other Collision |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| Forced Landing/UAS Fts Employed | C | RQ-7B | Engine Failure |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Uncommand Control Input |
| Other Collision | C | RQ-7B | Engine Over speed/Overtemp |
| Engine Failure | C | RQ-7B | Engine Over speed/Overtemp |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Electrical System |
| Hard Landing | C | RQ-7B | Engine Failure |
| | C | MAV | Other Collision |
| Electrical System | C | RQ-7B | Engine Over speed/Overtemp |
| | C | RQ-7B | Object Strike |
| Other Collision | C | RQ-7B | Landing Gear Collapse/Retraction |
| Other Collision | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Failure |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Over speed/Overtemp |
| | C | RQ-7B | Collision With Ground/Water |
| Other Collision | C | RQ-7B | Engine Failure |
| Undershoot | C | RQ-7B | Hard Landing |
| | C | PUMA | Collision With Ground/Water |
| Other Collision | C | RQ-7B | Engine Failure |
| | C | RQ-7B | Overshoot/Overrun |
| Engine Failure | C | RQ-7B | Engine Over speed/Overtemp |
| | C | RQ-7B | Overshoot/Overrun |
| Other Collision | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Failure |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Failure |
| Mast Bumping | C | MAV | Missing Aircraft/UAS |
| | C | PUMA | Other Collision |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Flight Control |
| | C | RQ-7B | Engine Failure |
| | C | RQ-7B | Collision With Ground/Water |
| Other Collision | C | RQ-7B | Flight Control |
| Other Collision | C | RQ-7B | Engine Over speed/Overtemp |
| | C | PUMA | Missing Aircraft/UAS |
| Mid-Air Collision | C | PUMA | Multiple Aircraft Event |
| | C | PUMA | Other Collision |
| Other Collision | C | RQ-7B | Engine Failure |

| | | | |
|---|---|---|---|
| Ditching | C | MQ-5B | Contractor Aircraft Accident |
| | C | RQ-7B | FTS Parachute Failure |
| | C | RQ-7B | Engine Failure |
| | C | RQ-7B | Other Collision |
| Forced Landing/UAS FTS Employed | C | SFOZ | Contractor Aircraft Accident |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Engine Failure |
| | C | MQ-5B | Undershoot |
| Other Collision | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Failure |
| Engine Failure | C | RQ-7B | Forced Landing/UAS FTS Employed |
| Other Collision | C | RQ-7B | Engine Failure |
| Wheels Up Landing | C | RQ-7B | Collision With Ground/Water |
| Forced Landing/UAS FTS Employed | C | RQ-7B | Fuel Starvation |
| | C | MQ-5B | Overshoot/Overrun |
| Other Collision | C | RQ-7B | Forced Landing/UAS FTS Employed |
| | C | PUMA | Other Collision |
| | C | RQ-7B | Other Collision |
| Other Collision | C | RQ-7B | Electrical System |
| | C | RQ-7B | Engine Failure |
| Engine Failure | C | RQ-7B | Engine Over speed/Overtemp |
| | C | MQ-5B | Other Collision |
| | C | MQ-5B | Other Collision |
| | C | MQ-5B | Other Collision |
| | C | PUMA | Object Strike |
| Other Collision | C | RQ-7B | Electrical System |
| | C | RQ-7B | Parachute Deployment |
| Other Collision | C | RQ-7B | Engine Failure |
| | C | PUMA | Other Collision |
| Other Collision | C | RQ-7B | Engine Failure |
| Other Collision | C | PUMA | Uncommand Control Input |
| Other Collision | C | RQ-7B | Airframe |
| | C | RQ-7B | Airframe |
| Other Collision | C | PUMA | Engine Over speed/Overtemp |
| Other Collision | C | RQ-7B | Transmission Failure |
| Other Collision | C | PUMA | Uncommand Control Input |
| | C | PUMA | Other Collision |
| Other Collision | C | RQ-7B | Engine Failure |
| Other Collision | C | RQ-7B | Engine Failure |
| | C | PUMA | Collision With Ground/Water |
| | C | MQ-1C | Hard Landing |
| | C | | |
| | C | RQ-11B | |
| | C | RQ-7B | |

| | | | |
|---|---|---|---|
| | C | RQ-7B | |
| | C | MQ-1C | Collision With Ground/Water |
| | C | MQ-1C | |
| Collision With Ground/Water | C | RQ-7B | Uncommand Control Input |
| Collision With Ground/Water | C | RQ-7B | Uncommand Control Input |
| | C | RQ-7B | Other Collision |
| Other Collision | C | RQ-7B | Uncommand Control Input |
| | C | RQ-7B | Automatic Take Off/Landing System (ATLS) |
| | C | RQ-7B | Other Collision |
| | C | RQ-7B | Other Collision |
| | C | RQ-7B | Engine Failure |
| | D | RQ-11B | Other Collision |
| | D | RQ-11B | Other Collision |
| Overshoot/Overrun | D | RQ-7B | Tactical Automated Landing System (TALS) |
| Missing Aircraft/UAS | D | RQ-11B | Collision With Ground/Water |
| Arresting Gear Failure (Drum, Strap, Pendant) | D | RQ-7B | Overshoot/Overrun |
| | D | RQ-7B | Overshoot/Overrun |
| | D | RQ-7B | Engine Failure |
| Missing Aircraft/UAS | D | RQ-11B | Avionics |
| | D | RQ-7B | Object Strike |
| | D | RQ-11B | Antenna Strike |
| Arresting Gear Failure (Drum, Strap, Pendant) | D | RQ-7B | Overshoot/Overrun |
| Missing Aircraft/UAS | D | RQ-11B | Uncommand Control Input |
| | D | RQ-7B | Overshoot/Overrun |
| Overshoot/Overrun | D | RQ-7B | Tactical Automated Landing System (TALS) |
| | D | RQ-11B | Other Collision |
| | D | MQ-5B | Object Strike |
| Collision With Ground/Water | D | RQ-11B | Avionics |
| Hard Landing | D | RQ-7B | Overshoot/Overrun |
| | D | MQ-5B | Airframe |
| | D | MQ-5B | Landing Gear/Arresting Hook |
| Missing Aircraft/UAS | D | RQ-11B | Collision With Ground/Water |
| | D | MQ-1C | Landing Gear/Arresting Hook |
| Collision With Ground/Water | D | RQ-11B | Avionics |
| Collision With Ground/Water | D | RQ-11B | Avionics |
| Collision With Ground/Water | D | RQ-7B | Engine Failure |
| Missing Aircraft/UAS | D | RQ-11 | Collision With Ground/Water |
| | D | RQ-7B | Other Collision |
| | D | RQ-7B | Object Strike |

| | | | |
|---|---|---|---|
| | D | RQ-11B | Collision With Ground/Water |
| Hard Landing | D | RQ-7B | Engine Failure |
| Other Collision | D | RQ-7B | Engine Failure |
| | D | RQ-11B | Collision With Ground/Water |
| | D | MQ-1B | Engine Failure |
| | D | RQ-11 | Collision With Ground/Water |
| Fuel Starvation | D | MQ-5B | Electrical System |
| | D | WASP3 | Other Collision |
| | D | RQ-11B | Other Collision |
| Forced Landing/UAS FTS Employed | D | RQ-7B | Engine Failure |
| Missing Aircraft/UAS | D | RQ-11 | Tactical Automated Landing System (TALS) |
| Other Collision | D | RQ-7B | Power Train |
| | D | RQ-11B | Other Collision |
| | D | RQ-11B | Missing Aircraft/UAS |
| | D | MAV | Other Collision |
| Other Collision | D | RQ-7B | Landing Gear/Arresting Hook |
| | D | RQ-7B | Other Collision |
| | D | RQ-11B | Missing Aircraft/UAS |
| Engine Failure | D | RQ-7B | Engine Over torque/Overload |
| Other Collision | D | RQ-7B | Overshoot/Overrun |
| Engine Failure | D | RQ-7B | Engine Over torque/Overload |
| Other Collision | D | RQ-7B | Undershoot |
| | D | RQ-11B | Other Collision |
| | D | RQ-11B | Other Collision |
| | D | RQ-11B | Other Collision |
| Other Collision | D | RQ-11 | Flight Control |
| Other Collision | D | RQ-11 | Engine Failure |
| Ditching | D | RQ20A | Wheels Up Landing |
| Other Collision | D | RQ-7B | Overshoot/Overrun |
| Hard Landing | E | RQ-7B | Forced Landing/UAS FTS Employed |

# APPENDIX G

## WIKIMEDIA FOUNDATION TERMS OF USE

# Terms of Use

This is a human-readable **summary** of the Terms of Use.

*Disclaimer: This summary is not a part of the Terms of Use and is not a legal document. It is simply a handy reference for understanding the full terms. Think of it as the user-friendly interface to the legal language of our Terms of Use.*

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- **Lawful Behavior** – You do not violate copyright or other laws.
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# APPENDIX H

# INSTITUTIONAL REVIEW BOARD APPROVAL

## Oklahoma State University Institutional Review Board

| | | | |
|---|---|---|---|
| Date: | Monday, December 01, 2014 | **Protocol Expires:** | **4/20/2017** |
| IRB Application No: | ED1451 | | |
| Proposal Title: | Integration of Unmanned Aerial Systems into the US National Airspace System: A Correlation between Safety Record and Concerns | | |
| Reviewed and Processed as: | Exempt<br>**Modification** | | |

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s):

| | |
|---|---|
| Omar Hamilton<br>PSC 78 Box 3337 APO AP 963<br>APO, 96326 | Timm Bliss<br>318 Willard<br>Stillwater, OK 74078 |

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The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

Modification to 1) change subject population to USAF pilots and sensor operators, 2) conduct interviews via phone and email and 3) submit a FIOA request for findings of aviation accidents, incidents and mishaps.

Signature :

Hugh Crethar, Chair, Institutional Review Board

Monday, December 01, 2014
Date

(Air Force Pilot Name),

I am requesting your assistance with my research study for completion of my dissertation titled: "Integration of Unmanned Aerial Systems Into the US National Airspace System; A Correlation Between Safety Record and Concerns." I request your support with my study through completion of an online survey and follow up interview.

In accordance with Air Force Instruction 38-501, the solicitation for support needs to be completed outside of duty hours. Additionally, survey and interviews would have to be completed outside of duty hours and without use of government resources (email, computers, etc.). If you are interested and able to support my research, please contact me at omar.hamilton@okstate.edu from a non-government email.

Participants will be asked 30 questions surveying their knowledge and safety concerns related to unmanned aerial systems (UAS) and the National Airspace System (NAS). The online survey will take approximately 10-15 minutes to complete. Participation is completely voluntary. There are no known risks associated with this research study that are greater than those a person would find in daily life. Participants' responses will remain confidential, and no individual's answers can be identified.

Participants' responses will be collected using the online survey program Survey Monkey. Only the principal investigator (PI) will be able to access the data, which will be stored in PI's personal computer for three years after the research study has been completed.

At a later time to be determined, participants will be contacted for a one-on-one interview. This interview will take approximately 20-30 minutes and will be used to gain amplifying data to answers from the online survey. Responses will be collected using email, tape recording devices and note taking. Only the PI will have access to this data and no individual's answers, name, rank or unit affiliation can or will be identified.

Thank you again for your support with my research.

Respectfully,
Omar Hamilton

Okla. State Univ.
IRB
Approved 2-1-14
Expires 4-20-17
IRB # ED14-51

VITA

Omar Jerome Hamilton

Candidate for the Degree of

Doctor of Education

Thesis: INTEGRATION OF UNMANNED AERIAL SYSTEMS INTO THE US NATIONAL AIRSPACE SYSTEM; THE RELATIONSHIP BETWEEN SAFETY RECORD AND CONCERNS

Major Field: Applied Educational Studies (Aviation and Space Science)

Biographical:

Education: Completed the requirements for the Doctor of Education in Applied Educational Studies at Oklahoma State University, Stillwater, Oklahoma in December, 2015.

Completed the requirements for the Master of Science Aerospace Administration at Southeastern Oklahoma State University, Durant, OK, in May, 2004.

Completed the requirements for the Bachelor of Arts in History at University of Wisconsin, Madison, WI in May, 2001.

Experience: United States Air Force Officer, 2001 to present; Joint Interface Control Officer, Air Operations Center certified, Instructor Air Battle Manager

Professional Memberships: Phi Kappa Phi Honor Society, Veterans of Foreign Wars, Military Officers Association