PILOT SKILLS AND AERODYNAMIC KNOWLEDGE FOR OPERATING SMALLER UNMANNED AIRCRAFT SYSTEMS

by

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ABSTRACT

Controversy continues regarding the pilot skills and aerodynamic knowledge necessary to operate smaller unmanned aircraft systems (UAS). Unmanned aircraft (UA) have been utilized successfully in the U.S. military for more than 20 years. Currently there is significant interest in integrating UAs into the National Airspace System (NAS) for government and civilian applications. There are no operating or certification rules or regulations specific to UAS, only policy and guidance, therefore they need to be developed. Understanding what UAs are, how they operate, what relevant human factors issues need to be addressed, and directing effective research will be necessary for successful integration into the NAS.

A survey tool was created using information on UAS training developed by an RTCA committee and referencing a UAS survey that was distributed by UVS International in 2009. The survey tool was sent to aviation industry professionals and enthusiasts electronically. The intent of the survey was to capture UAS type design and operational data as well as training data from respondents with knowledge and/or experience with UAS.

Of the 80 surveys completed, 58 fit the established criteria for evaluation. Every operational category was represented providing for a good cross-section of the industry as it is today. A baseline of information regarding aeronautical knowledge and experience

for operating smaller UAS was collected. Based on the data collected, for pilots operating UAs weighing less than 5 pounds and below 400 feet, there does not appear to be a need to require any specific training. However, for UAs weighing 5 pounds or more and operating above 400 feet, they should be regulated and pilots should obtain some kind of pilot certificate or operating privilege to operate in the NAS.

Going forward, in order for the FAA to establish an effective and appropriate UAS pilot certification structure, it would be beneficial for future research to look at why certain areas of operation are not always trained, how much time is spent learning specific tasks or in specific operational areas, defining what experience a UAS pilot could have that could mitigate the amount of training time required to be qualified to operate a UAS, and obtaining additional details surrounding the testing and/or checking of a UAS pilot.

CHAPTER I

INTRODUCTION

Unmanned aircraft systems (UAS) are currently transitioning from military applications to civil government applications in the United States (U.S.) national airspace system (NAS). In addition, there is a strong desire by many in the aviation industry to use UAS for commercial purposes. Pressure for greater access to U.S. airspace for UAS continues to grow. Pressure on the Federal Aviation Administration (FAA) is being applied by other government agencies wanting airspace access for training, environment monitoring, law enforcement and disaster response (Warwick, & Mecham, 2008).

The U.S. Customs and Border Patrol is currently utilizing UAS along the Mexican and Canadian borders of the U.S. for surveillance and protection (Associated Press, 2009). Other potential commercial applications for UAS include: agricultural, geological, meteorological, security monitoring, police surveillance, cargo hauling, search and rescue, and satellite transport, among others (McCarley & Wickens, 2005). According to a 2009 survey conducted by UVS International, there are a number of non-military scientific and research applications of UAS in the U.S., which include: agricultural and crop monitoring, arctic research, meteorological research, wildlife census, marine mammal monitoring, and vegetation identification (UVS International, 2009). The UVS International survey also reported security-related UAS activities in the U.S., which include: border surveillance, forest fire fighting support, and natural disaster surveillance (2009).

While the military has been operating UAS for decades, currently there are no UAS-specific standards or regulations established by the FAA, which are necessary for complete integration into the NAS. UAS operators currently have to conform to the current regulations for manned aircraft and apply for the operating privilege from the FAA referencing established FAA guidance.

The FAA chartered an aviation rulemaking committee (ARC) in April 2008, for several reasons, one of which was to provide recommendations for governing small UAS. The FAA has not yet defined small as it pertains to UAS. The ARC charter mentions that the Academy of Model Aeronautics (AMA) considers small UAS to be less than 55 pounds (FAA, 2008). The ARCs recommendations were provided to the FAA in March 2009 (D. Marshall, March 31, 2009, personal communication). These recommendations should lead to the first regulatory action by the FAA for UAS.

The FAA currently has a rulemaking project underway titled Operation and Certification of Small Unmanned Aircraft Systems (sUAS). According to the Department of Transportation's (DOT) July 2010 Report on DOT Significant Rulemakings, the sUAS notice of proposed rulemaking is scheduled to be published for public comment on March 10, 2011 (DOT, 2010). A final rule is anticipated in 2012 after reviewing all of the public comments.

Because of the changing dynamics of this emerging industry, these first requirements will likely come as a special federal aviation regulation (SFAR) (D. Marshall, March 31, 2009, personal communication). An SFAR will be limited in scope and provide the FAA with more flexibility in developing the requirements and time to collect additional data in support of future regulatory action.

Statement of Problem

One of the many difficulties in developing standards and regulations for UAS is that very little scientific human factors research is available to support them. This is, in part, because it is a rapidly evolving technology that was primarily used in the military, until relatively recently.

Echoing the need for further research, an extract from the 2007 Unmanned Systems Roadmap, published by the Department of Defense (DoD), states some of the UAS-related training is a “fundamental shift away from the skills needed to fly a manned aircraft” (p. 93). In that same year, the FAA stated in a final report providing recommendations on UA pilot medical certification requirements that additional human factors research was necessary “to investigate the effects on pilot performance of different types of console display interfaces; how UA flight mission profiles affect pilot workload, vigilance, fatigue, and performance; and to determine whether prior flight experience is important in both training and operation of UA” (Williams, 2007, p. 1).

In a report published by the DOT, Williams (2008) analyzed sensory information in the operation of UAS. The report states the “separation of the pilot control interface from the aircraft has consequences for the pilot in terms of the types and quality of sensory information available” (Williams, 2008, p. 1). The report also concluded that a UA pilot is at a disadvantage in being able to diagnose and respond to system anomalies (p. 20). A pilot not being able to hear engine noise, auditory alerts, or feel turbulence presents the need for further human factors research.

Purpose of Study

The purpose of this research is to determine what physical flying skills and aerodynamic knowledge is necessary to operate a smaller UAS. It is also looking to see if there are physical flying skills that can be universally applied or if there are type-specific skills that are unique to a particular design of UAS that need to be learned.

Significance of the Study

According to the FAA Aerospace Forecast Fiscal Years 2009-2025 (p. 46), there are around 100 U.S. companies, academic institutions, and government organizations developing over 300 UAS designs. The three major market segments: military, civil government, and commercial, all share a common objective, which is to provide a service that cannot be accomplished by manned aircraft and/or to perform an existing manned operation at a lower cost (FAA, 2009).

The U.S. and other aviation regulatory bodies around the world are looking to develop UAS certification standards for both aircraft and pilots to enable their use outside of the military. The difficulty falls in designing these standards, specifically pilot standards, based on scientific research to ensure minimum safety standards are met. As predicted in the FAA's rulemaking charter (2008), small UAS will experience the largest near-term growth in civil/commercial UAS.

Research Questions

The following is a list of questions that the researcher will examine and answer based on the findings of the study.

1. Are there general physical flying skills that could be applied universally and basic aerodynamic knowledge that a pilot must learn to successfully operate a smaller unmanned aircraft?
2. Are there unique design characteristics of smaller unmanned aircraft that would require type-specific training for pilots of smaller unmanned aircraft?

Conceptual Framework

This research will examine the physical flying skills necessary to operate a smaller UAS as well as what aerodynamic knowledge is necessary to operate a smaller UAS. The survey will be distributed among aviation professionals and enthusiasts electronically. While there may be international participation, the focus of this study is for UAS operations in the U.S. and experience with UAS weighing less than 500 pounds. The respondents will be compared based on the weight of their UAS, whether or not pilots complete an established, formal flight training program, and if any of the UA pilots are required to hold a pilot certificate. The information collected will also include information on the type of training accomplished, general content of the training, and if there is required type-specific training.

Definitions

The following words and phrases are found extensively in the research surrounding UAS. Referencing these will assist in further understanding of unmanned aircraft and their operations.

Aerodynamics is a branch of dynamics that deals with the motion of air and other gaseous fluids and with the forces acting on bodies in motion relative to such fluids

(Merriam-Webster Dictionary, 2009). It seeks to explain the principles governing the flight of aircraft, rockets, and missiles (Encyclopedia Britannica, 2009).

A *Certificate of Waiver or Authorization* (COA) is available to public entities, such as government agencies (including local law enforcement and state universities), who want to fly a UAS in civil airspace. An online application is made and the FAA evaluates the request. If the risks can be appropriately mitigated, the FAA issues a COA. Overall, the COA process works well, enabling public operators to conduct training and operational missions (FAA Fact Sheet, 2010).

Instrument meteorological conditions (IMC) is a term used to define the meteorological conditions in flight. The conditions are expressed in terms of visibility, distance from cloud, and ceiling less than the minima specified for visual meteorological conditions. If flying in the clouds, for example, you are considered to be operating in IMC (FAA P/CG, 2010).

A *model aircraft* is a non-human carrying device capable of sustained flight in the atmosphere. Its intended use is exclusively for recreational or competition activity (AMA, 2009). These models may fall into a future category of UAS that will be regulated.

A *nautical mile* is a unit of length used in sea and air navigation, based on the length of one minute of arc of a great circle, especially an international and U.S. unit equal to 1,852 meters (about 6,076 feet) (Answers.com, 2009).

An *optionally piloted aircraft* (OPA) allows for a pilot to be onboard an aircraft that can otherwise be controlled remotely and control the aircraft as a mitigation strategy in the event of lost communications. According to the FAA, an OPA is considered a UA any time it is controlled from outside of the aircraft, regardless if a pilot is onboard (FAA UA Program Office, 2008).

A *pilot in command* (PIC) is the pilot responsible for the UAS flight operation and retains complete and overall responsibility for the flight, regardless of who may be piloting the UA (FAA UA Program Office, 2008).

A *Prohibited Area* contains airspace with defined dimensions identified by an area on the surface of the earth within which the flight of aircraft is prohibited. Such areas are established for security or other reasons associated with the national welfare. These areas are published in the Federal Register and are depicted on aeronautical charts (FAA AIM, 2008).

A *public aircraft* is an aircraft operated by a public user, which is intrinsically governmental in nature, and not operated commercially or is carrying an individual that is not a crewmember or a qualified noncrewmember (FAA Definitions and Abbreviations, 1962).

A *Remotely Piloted Aircraft* (RPA) is another term for UA, used by the U.S. Air Force. The U.S. Air Force has established a new officer career path and planned to begin RPA undergraduate training beginning in October 2010 (Air Force, 2010).

A *Restricted Area* contains airspace identified by an area on the surface of the earth within which the flight of aircraft, while not wholly prohibited, is subject to restrictions. Activities within these areas must be confined because of their nature or limitations imposed upon aircraft operations that are not a part of those activities or both. Restricted areas denote the existence of unusual, often invisible, hazards to aircraft (FAA AIM, 2008).

A *small UAS* (sUAS) has not yet been officially defined by any regulatory body or industry group as of October 2010. However, 55 kilograms, or 121 pounds, seems to be an accepted number. For this research, it is assumed a *smaller UAS* is one that weighs less than 500 pounds.

Currently, for civil operations, private industry applicants must obtain a *Special Airworthiness Certificate*, *Experimental Category*, by demonstrating that their UAS can operate safely within an assigned flight test area and cause no harm to the public. Applicants must be able to describe how their system is designed, constructed and manufactured; including engineering processes, software development and control, configuration management, and quality assurance procedures used, along with how and where they intend to fly (FAA, 2008).

A *Special Federal Aviation Regulation (SFAR)* is a temporary rule for a temporary situation. An SFAR is still subject to all of the requirements and procedures of the Federal rulemaking process (T. Adams, April 28, 2009, personal communication).

Unmanned aircraft (UA) is the flying portion of the unmanned aircraft system. It is flown by a pilot via a ground control system or autonomously through the use of an onboard computer, communication links, and any additional equipment that is necessary for the UA to operate safely (FAA UAPO FAQ, 2010).

An *unmanned aircraft pilot* is the individual that maneuvers, controls, and monitors the UA (RTCA SC-203, p. 8).

An *unmanned aircraft system* (UAS) is a UA and its associated elements required to operate in the NAS (RTCA SC-203, p. 3). The associated support equipment may include: a control station, data links, telemetry, and communications and navigation equipment (FAA UAPO FAQ, 2010).

Visual meteorological conditions (VMC) is another way of describing the meteorological conditions one is flying in. The conditions are expressed in terms of visibility, distance from cloud, and ceiling equal to or better than specified minima. If operating outside of the clouds, for example, one is said to be operating in VMC (FAA P/CG, 2010).

A *visual observer* is an individual who maintains visual contact with the UAS while scanning the immediate environment for potential conflicting traffic. The information must be able to be provided to the UAS pilot (FAA UA Program Office, 2008).

A *Warning Area* is airspace of defined dimensions, extending from three nautical miles outward from the coast of the U.S., which contains activity that may be hazardous to nonparticipating aircraft. The purpose of such warning areas is to warn nonparticipating pilots of the potential danger. A warning area may be located over domestic or international waters or both (FAA AIM, 2008).

Assumptions

1. The individuals that respond to the survey will have the specific knowledge to answer the questions accurately.
2. The individuals that respond to the survey will provide factual information, not anecdotal based on their opinion, with the exception of the questions that solicit opinion.

3. Individuals who received training will recall specifically what was taught and/or tested.

Limitations

1. This research will be distributed to aviation industry professionals that may not have experience and/or knowledge with UAS.
2. To narrow the scope, only responses by those with experience and/or knowledge of UAS in the U.S. will be considered.
3. To narrow the scope, only responses by those with experience and/or knowledge of UAS weight less than 500 pounds will be considered.
4. The training information collected will be based on individual responses rather than a review of actual training material.

Literature Review

Sport Pilot and Light-Sport Aircraft

In February 2002, the FAA proposed a new rule for the certification of aircraft and airmen for the operation of light-sport aircraft. The FAA believed this action was necessary to address advances in sport and recreational aviation technology as well as gaps in the existing regulations. The intended effect of this action was “to provide for the manufacture of safe and economical aircraft and to allow operation of these aircraft by the public in a safe manner” (FAA Certification of Aircraft and Airmen for the Operation of Light-Sport Aircraft, 2002, p. 5368). The reasoning for this rule could also potentially be used for UAS.

The FAA proposed, and eventually added, two new pilot certificates as well as two new aircraft category ratings to allow operations of light-sport aircraft. To fly different makes and models of light sport aircraft, a pilot needs to receive and log aircraft-specific ground and flight training from an authorized instructor. To fly additional categories and classes of light-sport aircraft, a pilot would not only have to log ground and flight training in certain operational areas from an authorized instructor, but complete a proficiency check with a different authorized instructor. A logbook endorsement would be required to show a pilot is qualified (FAA Certification of Aircraft and Airmen for the Operation of Light-Sport Aircraft, 2002).

In its proposed rule, the FAA made a safety case for the benefits of certificating sport pilots and light sport aircraft. The FAA did this by identifying a number of factors related to training and certification that contribute to the prevention of accidents. Specifically for sport pilots, they would: meet minimum requirements to be eligible to operate aircraft, be trained and tested to a standard, and be required to complete recurrent training, which would maintain pilot skills, to list a few of the potential training and certification factors (FAA Certification of Aircraft and Airmen for the Operation of Light-Sport Aircraft, 2002, p. 5374).

In the FAA's proposed rule (2002), there was an explanation of what aeronautical experience and aeronautical knowledge a student pilot would have to have in order to apply for a sport pilot certificate. The proposed flight time minimums were listed for the aeronautical experience as well as the proposed aeronautical knowledge areas. The FAA determined those hour requirements and knowledge areas by basing them partly on existing criteria for 14 CFR 103 FAA-recognized training programs and partly on criteria contained in 14 CFR 61 for existing pilot certificates. There was no scientific data supporting the hours they chose. The FAA did mention the reduced complexity of the light-sport aircraft as well as the operating environment as reason for the lesser requirements when compared to a recreational or private pilot certificate (FAA Certification of Aircraft and Airmen for the Operation of Light-Sport Aircraft, 2002).

Model Aircraft

FAA Advisory Circular (AC) 91-57 (1981) provides the operating standards for flying model aircraft. It recommends flying away from populated areas, no higher than 400 feet above the surface, and not within 3 miles of an airport unless the airport or air traffic control has been notified. It also advises observers to give the right of way and to avoid flying in the proximity of full-scale aircraft.

The AMA expands on this AC with significant detail in its National Model Aircraft Safety Code (2010). While it includes the recommendations of AC 91-57, it also provides a suggested maximum takeoff weight, including fuel, of 55 pounds. It discourages the use of certain fuel types as well as operator use of alcohol within eight hours of flying a model aircraft, or operator use of any drugs that could adversely affect safely controlling the model aircraft. A key statement in the radio control portion of the AMA Safety Code (2010) is the operator shall control the model aircraft during the entire flight, maintaining visual contact without enhancement, other than corrective lenses. It also states the model aircraft should not be equipped with devices which would allow it to be flown to a selected location beyond the visual range of the operator.

There are two types of flying model aircraft: free flight or radio controlled (R/C). They can be launched by throwing them into the air or by taking off from the surface.

A Web Site for model flyers in the United Kingdom provides information for newcomers to R/C flying. It states R/C models are just like a real aircraft and operate by the same principles; the only difference is the size and weight. It also states you have to be taught to fly and that it is a skill to be learned (Flying Sites, 2009).

Another Web Site for R/C flyers provides a wealth of information for all experience levels. In the introduction to its aerodynamics section, it strongly recommends a basic knowledge of aerodynamic principles before getting involved with flying R/C aircraft (Welcome to Model Aircraft, 2009).

Types of Military UAS

There are varying operational designs of UAS that provide a unique set of human factors to consider. The military has the most experience with UAS, or RPA, and operates a number of different types of UAS. Recently the Air Force has initiated the RPA career path that will include undergraduate RPA training (Air Force, 2010). Most would not be considered small based on their weight, but familiarity with their operational characteristics are important.

The Global Hawk, operated by the U.S. Air Force, for example, is completely autonomous. The route or mission is preprogrammed prior to departure. There is a crew that monitors both the status of the UAS and the payload, but there are typically no human inputs once launched, though there is the capability for it (Williams, 2004).

The Shadow, operated by the U.S. Army, utilizes a launcher for takeoffs and the Tactical Automated Landing System (TALS) during the approach and landing phase. Therefore a pilot is not needed during these phases unless the TALS system were to fail or intervention is required. Aircraft control during flight is accomplished by a pilot located at a Ground Control Station (GCS) solely by inputting information into a computer system (Williams, 2004).

The Hunter, also operated by the U.S. Army, requires a pilot to operate a controller while having visual contact with the UAS during takeoff and landing. The flight portion, outside of the takeoff and landing, is transferred to a pilot at a GCS. Flight parameters (altitude, heading, and airspeed) are set using knobs located within the GCS (Williams, 2004).

The Pioneer, formerly operated by the U.S. Navy, was similar in operation to the Hunter in that it required a pilot with visual contact for the takeoff and landing. In flight, the Pioneer was operated in one of three modes. The first mode was autonomous utilizing preprogrammed waypoints. The second mode required a pilot in the GCS to set knobs controlling the flight parameters. The third mode allowed for the pilot in the GCS to utilize a joystick and actually fly the UAS (Williams, 2004).

The Predator, flown by the U.S. Air Force, operates similarly to a manned aircraft in that the pilot actually flies it by using a joystick, rudder pedals, and has a forward-looking camera with a 30-degree field of view (Williams, 2004).

Military UAS Accident Data

A summary of UAS human factors implications using military UAS accident and incident data was completed by the FAA's Civil Aerospace Medical Institute (Williams, 2004). Its purpose was "to determine to what extent human error has contributed to those accidents and to identify specific human factors involved in the accidents" (Williams, 2004, p. 1). Data was collected from the Army, Navy, and the Air Force. Important information was drawn, though the data received lacked detail because it consisted of primarily summaries of several accidents or one-sentence statements regarding individual accidents.

The data was first divided into two broad categories, human factors or aircraft component failure (Williams, 2004). It was possible for one accident to be classified into both categories. Each of those categories was further divided. Human factors were classified under alerts/alarms, display design deficiencies, procedural errors, and skill-based errors (Williams, 2004).

Beginning with the Army data (Williams, 2004), there were 74 accidents involving UAS between March 2, 1989 and April 30, 2004. The Hunter accounted for 32 accidents and the Shadow accounted for 24 accidents. The other 18 concerned other UAS (Williams, 2004). The analysis further focused on the Hunter and the Shadow accidents.

Of the 32 Hunter accidents, 15 had one or more human factors issues associated with them (Williams, 2004). As mentioned previously, the Hunter requires a pilot to have visual contact with the UAS for takeoff and landing. Forty-seven percent of the human factors related accidents occurred during the landing phase, with an additional 20 percent of the accidents occurring during takeoff (Williams, 2004). One key human factors issue to note is the separation of the man and machine and its impact on controllability. “When the aircraft is approaching the pilot, the control inputs to maneuver the aircraft left and right are opposite what they would be when the aircraft is moving away from the pilot” (Williams, 2004, p. 4). Other human factors issues noted were with PIC authority, display design, and procedural errors.

In a review of the Shadow accidents, only five of the 24 accidents were attributed to human factors issues (Williams, 2004). Because the Shadow uses a launcher for takeoffs, that issue is removed from possible human error. The TALS landing system is also not a function of human error, but it did contribute to 25 percent of the Shadow accidents (Williams, 2004). The human considerations were evenly distributed between the four categories, each with two.

There were two significant human error issues noted in the summary. In one scenario a GCS crew was issued a command to shut down the engine to a damaged UAS after a TALS failure (Williams, 2004). The command was not received because of a damaged antenna. This same crew was then tasked with controlling another Shadow. The engine shut down command was still waiting for confirmation from the GCS software, which was received by the second UAS, causing it to crash. The crew failed to follow all checklist items when transferring control and there was a design display issue because there was no clear indication to the crew as to the status of the message (Williams, 2004).

The second accident scenario referenced also had control transfer problems from one GCS to another. The second operator station had a fuel control switch out of position causing the engine to quit once control was transferred (Williams, 2004).

The Navy provided accident data for the Pioneer from 1986 to 2002, the year they stopped flying it (Williams, 2004). There were 239 accidents of which 68, or 28 percent, were related to human factors issues. The largest percentage of the 68 accidents occurred during the landing phase, 68 percent with an additional 10 percent for takeoff (Williams, 2004). It is important to note that the Pioneer primarily used a launcher for the takeoffs. Other human errors noted were aircrew coordination, which includes procedural errors, communication errors, and weather-related accidents, which dealt with pilot decision-making (Williams, 2004). There were insufficient details to provide for further analysis beyond these statistics.

Of the total Predator accidents, 67 percent were attributed to human error (Williams, 2004). A majority of those accidents were procedural errors. Notable procedural errors consisted of failing to complete a checklist properly and software interface issues (Williams, 2004). To elaborate further on the software issues, assignment of menu selections to function keys on the GCS keyboard created problems when the proper order was not followed by the crew. Other reported issues were display design of the head-up display, head-down display, inadequate alerts and alarms, and autopilot function (Williams, 2004). A potentially significant autopilot problem for the Air Force is its functionality does not conform to Air Force standards because it uses pitch to adjust for airspeed instead of power. "This could result in the pilot not being fully aware of what changes were being made by the autopilot maneuvering" (Williams, 2004, p. 11).

Only three accidents were available for the Global Hawk. Only one was attributed to human error during the mission-planning process. The crew was unaware that the taxi speed was entered at 155 knots as a result of a software bug. The aircraft accelerated too quickly and was unable to negotiate a turn and went off of the runway causing extensive damage (Williams, 2004).

UAS Human Factors

The summary of UAS human factors implications using military UAS accident and incident data concluded "many of the human factor issues identified are very much dependant on the particular systems being flown, the type of automation incorporated, and the user interface employed" (Williams, 2004, p. 12). There is some evidence that a lack of sensory information to a UA pilot has an impact on the safety of flight. It is estimated that 15 percent to 25 percent of UAS accidents are due at least in part to lack of sensory information (Williams, 2008, p. 20).

To establish standards and regulations, researchers and lawmakers question what human factors research needs to be accomplished. In a technical report prepared for the FAA in April 2005 by the Institute of Aviation at the University of Illinois at Urbana-Champaign, 18 human factors research topics unique to UAS operations were identified (McCarley, et al, 2005). The issues were wide-ranging and included UAS operations, pilot control interface, procedural issues, and crew qualifications.

Beginning with UAS operations (McCarley, et al, 2005), determining to what extent they should be automated will be difficult. Regardless of the type of UAS, there will be some level of automation. Based upon the accident data previously reviewed, there is not a single obvious answer and there may be more than one answer. The answer may depend upon the characteristics of the flight operation; whether a single operator will be able to control more than one UAS at the same time, communication delays between the operator and the UAS, and the quality of visual imagery provided to the operator (McCarley, et al, 2005). The level of automation analysis will need to be assessed not only for the flight portion, but also for the level of automation required for the takeoff and landing phases. Determination of reliability levels for the support systems will need to be established as well as anticipating system failures, consequences, and operator response. Estimating the reaction time necessary by the operator to respond to systems failures and determining the proper operator techniques will be important. The operator will essentially have different types of emergency checklist items or abnormal checklist items to respond to (McCarley, et al, 2005).

A second critical area of research deals with the pilot interface (McCarley, et al, 2005). Deciding what form of control interface pilots should have to manipulate the UAS, both visually and from a GCS will be necessary. Approval of a single type design will have to be decided, or a determination that the designs can vary based upon the operation. Current GCS systems vary in control design from a stick and rudder, to knobs or position switches, to mouse point-and-click computer menus (McCarley, et al, 2005). While these designs should be further researched, other interfaces should also be considered for improved human performance.

As mentioned previously, the pilot using a remote control device while visually controlling the UAS has significant human factors issues in that the control input varies depending on the heading of the UAS in relation to the pilot. The visual display and symbology used need further assessment for the GCS (McCarley, et al, 2005). An area of particular interest is determining what the appropriate field of view is since some claim, for those designs that provide for it, that the field of view is too small.

Also a consideration for improved displays is utilizing multimodal display technology, which would include tactile and auditory alerts and displays in addition to the visual displays (McCarley, et al, 2005). There is concern that with the separation of pilot and aircraft that many sensory inputs are lost and they cannot all be visually displayed or effectively processed by a human (McCarley, et al, 2005). While it is understood that no single display will be optimal for all operations, questioning whether or not there should be some consistency or standardization to the display, like the “Basic T”, for example, is important. Deciding what information should always be displayed and determining whether or not certain controls should be mandatory for specific functions to prevent negative transfer between UAS is also an important factor (McCarley, et al, 2005).

An additional consideration with the separation of pilot and aircraft is determining if the pilot's perception of risk is different than a pilot who is actually in an aircraft (McCarley, et al, 2005). If the perception of risk is different, follow-up questioning to determine whether or not the absence of sensory or perceptual cues is a contributor to the shift in risk will provide valuable information.

The third area addressed in the report relates to air traffic management and procedural issues (McCarley, et al, 2005). As discovered in the analysis of the military accident data, a number of the accidents were a direct result of control transfer between crews or GCSs. It was recommended that formal procedures for UAS handoff control be developed and tested in addition to developing and testing displays, automation, and procedures to ensure operators receiving the control are informed of system status and proper configuration (McCarley, et al, 2005). Communication between air traffic control and the UAS operator needs to be evaluated for possible time delays and for proper response to a loss of communication between them. Also, determining what predictable behavior the UAS will have should the data link be lost between the operator and the UAS is necessary, as well as the kind of alert to the operator should the link be lost (McCarley, et al, 2005).

The final area addressed in the report was crew qualifications (McCarley, et al, 2005). The certification of a pilot or operator needs to be built from the ground up; beginning with questioning whether or not manned pilot experience should be required. Determining the skills and knowledge necessary for a certificate and how the ratings will work for various types of UAS will be required. A review of pilot responsibilities and the workload while operating UAS will also be required (McCarley, et al, 2005). Is it feasible, under any circumstances, for a single pilot to operate a UAS? If so, would operating more than one UAS simultaneously be plausible and safe? Is it appropriate to require a medical certificate and would all of the current FAA medical policies regarding specific medical conditions apply? These are some of the many certification questions that will require further human factors research (McCarley, et al, 2005).

To date, there is no other research available that corroborates these findings or disproves them. However, to add some validity to the findings, the RTCA Committee 203 is a large group of industry representatives and FAA personnel working towards finding the solutions to many of the questions and issues identified in this section.

UA Pilot Requirements

In 2007, a final report was published on UA pilot medical certification requirements (Williams). In the research that was accomplished to provide UA pilot medical certification requirements, Williams (2007) reviewed existing research on UA pilot certification requirements. The first relevant research Williams (2007) found was conducted in 1973 with the Navy. That research "hypothesized that a broader segment of relatively untrained personnel could be brought up to the required level of skill with short time simulation/training provided they meet some minimum selection criteria" (Williams, 2007, p. 1). The authors also concluded that the "performance control joystick was superior for aircraft control, regardless of the level of pilot experience" (Williams, 2007, p. 1).

Williams (2007) found an additional study in 2002 that looked at previous flight experience and its effect on learning to fly the Predator UAS. Seven different groups were used in the study with varying experience levels ranging from no pilot experience to Predator flying experience. The participants were evaluated on their stick and rudder skills, not on other general skills like pilot communication.

As expected, the group with no flying experience performed significantly worse than the other groups while the group with previous Predator experience performed significantly better (Williams, 2007, p. 2). What the authors did not expect was that the "participants with various levels and types of non-Predator flight experience all performed at relatively the same level on the Predator system" (Williams, 2007, p.2). "The authors concluded that any type of flight experience with an aircraft with similar handling characteristics to the Predator was beneficial for flight training on the Predator system" (Williams, 2007, p. 2).

FAA UAS Operational Approval Guidance

As the research continues, initial FAA operational approval and guidance for UAS operations in the NAS is becoming more defined. There are numerous UAS that have received a COA or an experimental airworthiness certificate from the FAA. Military operators of UAS are required to obtain a COA from the FAA, which accommodates UAS into the NAS when mission needs dictate (DoD, 2007). Experimental airworthiness certificates are issued to non-military UAS.

The COA process is available to public entities, such as government agencies (e.g., local law enforcement agencies and state universities), who want to fly a UAS in civil airspace. If the risks can be appropriately mitigated, the FAA issues a COA, generally based on the following principles:

- The COA authorizes an operator to use defined airspace and includes special provisions unique to each operation, which typically incorporates a specified time period that it is valid.
- The COA typically requires coordination with an appropriate air traffic control facility and may require the UAS to have a transponder to operate in certain types of airspace.
- Due to the UASs inability to comply with ”sense and avoid” rules, a ground observer or an accompanying “chase” aircraft must maintain visual contact with the UAS and serve as its “eyes” when operating outside of airspace that is restricted from other users. (FAA, 2010).

In 2005, the FAA issued its first and only experimental airworthiness certificate for UAS in that Fiscal Year (FY) to General Atomics (R. Posey, April 21, 2009, personal communication). Total to date, the FAA has issued 71 experimental certificates for 17 different aircraft types, 14 of which are currently active (FAA, 2010). Currently, the FAA has 247 active COAs, including 89 completed so far this year (FAA, 2010). An additional 153 applications are pending (FAA, 2010).

The DoD is working to refine or replace the COA process to enable more ready access to the NAS. With a couple of exceptions, the current process takes approximately 60 days to have a COA issued which is valid for 1 year (DoD, 2007) The DoD admits UAS reliability, conformance to FAA regulations, and see and avoid capability must be addressed before the COA process can be eliminated (DoD, 2007).

The FAA provides guidance to interested parties in obtaining a COA or experimental airworthiness certificate for their UAS in its Interim Operational Approval Guidance 08-01 (2008). The guidance only applies to those UAS operations affecting the NAS other than those located in active Restricted, Prohibited, or Warning Areas and those that are not completely autonomous. Unless authorized, for UAS operations outside of the Restricted, Prohibited, or Warning areas and outside of Class A airspace, a visual observer is required. This requirement is there for see and avoid purposes as an alternative form of compliance with 14 CFR 91.113, Right-of-Way Rules: Except Water Operations (FAA, 2008). The observers position relative to the UA will vary, but generally they should be no greater than one nautical mile laterally and 3,000 feet vertically from the UA (FAA, 2008, p. 9).

The FAA's interim guidance (2008) provides additional information for chase aircraft operations, on flying over populated areas, communication with air traffic control, airspace considerations, and day versus night operations. It also has a section on personnel qualifications, which includes the PIC, supplemental pilots, and observers. The UAS pilot qualifications listed in this section state (p. 14):

- One PIC must be designated at all times;
- The PIC of an aircraft is directly responsible, and is the final authority of, the operation of that aircraft;
- Pilots must not perform crew duties for more than one UAS at a time; and
- Pilots are not allowed to perform concurrent duties both as a pilot and observer. (p. 14)

This section also outlines which operations require a pilot certificate and which operations do not.

Operations requiring a pilot certificate are those approved operations conducted in Class A, B, C, D, and E airspace, those conducted under instrument flight rules (instrument rating required as well), those operations conducted at night, those conducted at joint-use or public airfields, and those conducted beyond the line-of-sight (FAA, 2008).

It is possible for the PIC to not be required to hold a pilot certificate if the approved operations are conducted solely within visual line of sight in Class G airspace and the PIC meets other established requirements. To be exempt, the following operational conditions must exist (FAA, 2008):

- The operation is conducted in a sparsely populated location;
- The operation is conducted from a privately owned airfield, military installation, or off-airport location;
- The PIC must have a visual line-of-sight of no further than one nautical mile laterally from the UA and at an altitude of no more than 400 feet above the ground;
- The operation must be during daylight hours; and
- The operation can be no closer than five nautical miles from any airport or heliport. (p. 15)

An alternative method of compliance for the PIC, in lieu of having a pilot certificate, is the PIC must have successfully completed, at a minimum, FAA-approved private pilot ground instruction and have passed the FAA written examination (FAA, 2008).

Additional PIC, supplemental pilot, and observer requirements include currency requirements, medical certificates, and manufacturer-specific training with demonstrated proficiency and testing (FAA, 2008).

RTCA Special Committee (SC)-203

SC-203 is a Special Committee established by RTCA, Inc. that is tasked with creating guidance material and developing the framework for Minimum Aviation System Performance Standards and Minimum Operational Performance Standards for UAS. SC-203 is made up of regulatory and UAS industry professionals. SC-203 has published a document, which includes an appendix with best practices for small UAS. For the best practices document, small UAS refers to “any remotely operated aircraft that is model-like in size [55 pounds or less] yet designed or modified for purposes other than recreational use” (p. I-1). The team that developed the best practices consisted of current pilots, operators, and manufacturers of small UAS, along with members of research organizations, aviation associations, and the FAA.

The best practices developed for small UAS cover a wide range of areas including design and construction, training, and operational areas like mission planning and shutdown. Focusing on the operational best practices, one recommendation states operators should ensure all persons involved in the operation are trained and sufficiently knowledgeable and skilled in their operational responsibilities (RTCA, 2007). The recommendations elaborate further on the recommended training suggesting pilots complete a training program that includes classroom study, field observation, and flight training for the specific UAS being operated (RTCA, 2007).

Knowledge of the NAS should include the following topics (RTCA, 2007):

- Airspace classifications and requirements;
- Air navigation facilities, equipment, and services;
- Airports and landing areas;
- Aeronautical charts and symbols;
- Aeronautical information services and sources;
- Applicable rules, regulations, and procedures; and
- Aeronautical information manual content overview. (p. I-6)

Knowledge of system operation, control interface, link management, normal and emergency procedures, safety handling, etc. for the specific UAS being operated should include the following topics (RTCA, 2007):

- Mission planning;
- Preflight procedures;
- Takeoff and transit to operations area;
- Flight operations;
- Recovery and landing;
- Post-flight procedures;
- Emergency procedures and contingency operations; and
- Maintenance procedures. (p. I-6)

The team has recommended operators determine adequate pilot skills for the specific UAS being operated. This should be accomplished by identifying the minimum skills for each proposed operation and conducting a proof of operator proficiency flight before operating outside of a test/training environment (RTCA, 2007).

Summary

After reviewing military, industry, and FAA UAS research, current FAA policy surrounding UAS, and related areas such as model aircraft and light-sport aircraft, it is clear that further research and data collection is necessary to develop the civilian regulatory framework in the U.S. for operating UAS in the NAS. With a broad range of UAS capabilities in the U.S., it is important to capture the very basic knowledge and skills necessary for operating UAS and then build on that as the complexity increases. Given there was no published research data available, this research focuses on collecting information on the basic knowledge and skills for operating smaller UAS from aviation industry professionals and enthusiasts with knowledge and/or experience with UAS.

CHAPTER II

METHODOLOGY

The purpose of this survey research was to generalize what, if any, physical flying skills a pilot should learn to operate a smaller UAS. Also evaluated is whether or not a basic knowledge of aerodynamics is necessary to operate a smaller UAS. Based on the questioning, the survey will determine if UAs will require a basic skill set that is transferrable from one UA to another. It will also determine if UAs also have unique characteristics that would require additional type-specific training.

The respondents will be compared based on the weight of their UAS, whether or not pilots complete an established, formal flight training program, and if any of the UA pilots are required to hold a pilots license. The information collected will also include information on the type of training accomplished, general content of the training, and if there is required type-specific training.

Population

The population of this study was aviation industry professionals and enthusiasts with knowledge and/or experience with UAS. The primary focus was to capture the involvement and opinion of those aviation industry professionals and enthusiasts whose knowledge and/or experience is based on UAS operations in the U.S. In addition, there was a predetermined UA weight limit of 500 pounds to ensure the data collected represented smaller UAS, as defined by this research. This weight limit was purposely larger than how small UAS might come to be defined to see if there was any variation in the responses as the weight increased.

Sample

A convenience sample was used. The survey tool was distributed solely by electronic mail. The cover letter information was incorporated into the electronic mail message and indicated the topic and who was eligible to participate. The message also incorporated a hyperlink to the survey. The primary distribution was via an electronic mailing list, which reaches more than 25,000 aviation industry professionals and enthusiasts (C. Lewis, February 3, 2010, personal communication). The U.S. readership of this mailing list is estimated at 75 percent (C. Lewis, February 3, 2010, personal communication). A secondary distribution of the survey tool was done amongst peers who are involved or know of others involved in UAS.

Research Design

The survey tool used a mixed method form of questioning. The questioning was a combination of finite and open-ended questions, which enabled collection of quantitative and qualitative data. There were a total of 20 questions in the survey, which should have taken 5 to 10 minutes to complete.

The two forms of data collected were UAS type-design and operational data and training program data. The first 11 questions collected quantitative data. The questions focused primarily on the UAS type-design and operational data, which provided information on the number of different types of UAs a respondent had experience with, the weights of the UAs, the operational characteristics of the UAs, whether or not the respondent had or participated in a formal training program, and the flying experience of the pilots of the UAs.

The training program data provided both quantitative and qualitative data on the knowledge and skills taught in the training program. This was captured in seven finite questions and two open-ended questions. The training program questioning focused specifically on aerodynamic knowledge and flying skills.

Data Collection Methods/Procedures

An online survey tool with a custom template was created through a Web site: www.surveymonkey.com. A hyperlink to the survey was sent via an electronic mail distribution list of aviation professionals and enthusiasts. It was also distributed amongst peers who are involved or know of others involved in UAS. The survey tool was first distributed on May 5, 2010. The hyperlink to the survey remained open for 30 days. A copy of the survey tool can be found in Appendix A. Categorical scales and continuous scales are used to analyze the quantitative data received. A tabled summary of the qualitative responses received can be found in Appendix B.

Instrument Reliability and Validity

This survey tool was modeled after a 2009 survey conducted by UVS International on light UAS. UVS International is a non-profit organization promoting international coordination and cooperation of UAS. In October 2009, UVS International had 261 corporate, academic, and institutional members in 37 countries and 10 international organizations on 5 continents (UVS, 2010).

The intent behind the UVS International survey was to collect qualitative data on global light UAS operations. On October 8, 2009, UVS International reported for the

European Commission Hearing for Light UAS that it had received 120 responses from organizations representing 27 countries worldwide (UVS, 2010). Many of the quantitative questions in this survey tool were designed to capture similar data as that which was captured in the UVS International survey.

The quantitative questions for this survey tool, which were designed to capture training program data, utilized some of the suggested training areas determined by RTCA SC-203 in their published best practices for small UAS. A small UAS, according to the RTCA SC-203 best practices document, refers to “any remotely operated aircraft that is model-like in size [55 pounds or less] yet designed or modified for purposes other than recreational use” (p. I-1).

All of the questions were reviewed by graduate faculty at the University of North Dakota as well as other industry experts in UAs.

Proposed Data Analysis

A comparative analysis of the quantitative data collected on the respondents is used as well as a descriptive analysis of both the type-design and operational data and training program data.

Protection of Human Subjects

This study did examine human subjects. Information containing individual or company names was not collected. The survey did not require the identification of any particular manufacturer, operator, military branch, government association, etc. On specific questions, respondents had the option of selecting “prefer not to disclose” and any question could be skipped if there were any concerns by the respondent on any particular question. The responses were not recorded until the “submit” button was selected. The respondent could have exited the survey at any time prior to selecting "submit". In addition, the study followed all prescribed rules and regulations pertaining to the University of North Dakota's Institutional Review Board (IRB) and the protection of human subjects and their information.

CHAPTER III

RESULTS

A total of 80 responses were submitted via the electronic survey tool. The survey contained 20 questions. The purpose of the first 11 questions was to learn about the respondent and the level of knowledge and/or experience with UAS. There were seven questions that followed that specifically covered UAS training. The remaining two questions were questions that asked for the opinion of the respondent and allowed for a free-form response.

The purpose of the survey was to collect data from individuals with knowledge and/or experience with UAS in the U.S., weighing less than 500 pounds. After reviewing the responses to question 2 and question 5, the total number of responses to be evaluated was reduced as a result of these established limitations.

There were 17 individuals who responded to the survey whose knowledge and/or experience of UAS was not in the U.S (question 2). Of the 63 U.S. respondents, 10 reported experience with UAS of 500 pounds or greater; 5 of which that was their only experience (question 5). Therefore, the results reported going forward will be based on the 58 U.S. respondents with knowledge and/or experience with UAS weighing less than 500 pounds.

Questions about the Respondent

Question 1 asked the respondent to describe his or her involvement with UAS. This particular question did not limit the respondent to one choice. The intent was to get a feel for the variety of experience the respondents have with UAs. The options provided were: manufacturer (design and/or produce UAs or R/C aircraft), operator (company that operates UAs or R/C aircraft), researcher (utilize UAs or R/C aircraft to conduct research), pilot (fly and/or operate UAs or R/C aircraft), training (provide training for pilots operating UAs or R/C aircraft), and other.

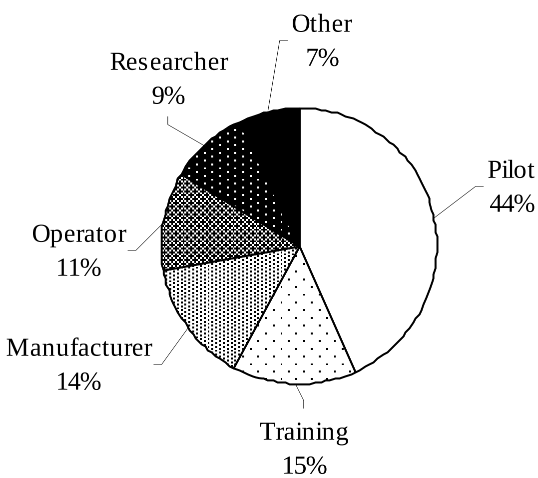

Figure 1. Respondent Involvement with UAS (Question 1)

Twenty-one respondents chose more than one option to describe their involvement. The breakdown of the responses to this question was: 14 manufacturers, 11 operators, 9 researchers, 42 pilots, and 14 training. There were seven other responses, which included government and FAA support.

With pilots being the most popular category, further analysis discovered 23 of the 42 respondents selected pilot as their only option. Nine of the 42 pilots did not complete any of the training questions. Of those nine pilots that did not respond to any of the training questions, eight selected recreational as their sole involvement with UAS in a later question. The other pilot that did not respond to the training questions listed government for his/her involvement. There were three respondents that only selected researcher and none of those three responded to the training questions. Of those that selected training, those individuals also selected another category of knowledge and/or involvement with UAS. For most of the respondents involved with UAS training, the other selection was pilot.

As previously indicated in this chapter, question 2 asked the respondent to indicate whether or not their involvement with UAS was in the U.S. This question was added to limit the scope of the survey. After reviewing 80 responses, 63 answered “yes”.

Question 3 asked the respondent to indicate how many UAS they were familiar with; 57 of the 58 individuals responded. Eight respondents indicated they are familiar with only 1 type of UAS; 15 respondents indicated they are familiar with 2 types of UAS; 4 respondents indicated they are familiar with 3 types of UAS, 23 respondents indicated they are familiar with at least 4 types of UAS, and 7 respondents preferred not to disclose how many they are familiar with. Of the seven respondents that preferred not to disclose the number of UAS they are involved with, three described their involvement as a manufacturer.

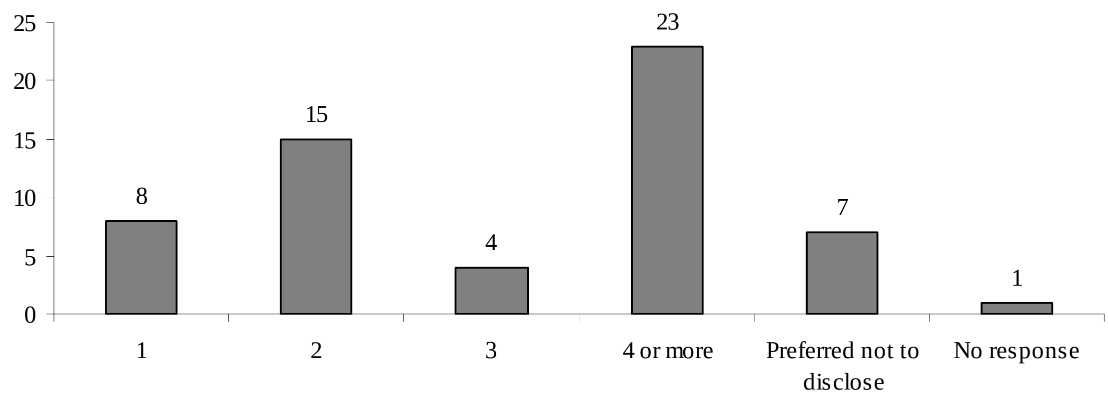

Figure 2. Respondent Familiarity with Types of UAS (Question 3)

Question 4 asked the respondent to describe the operational intent of the UAS they were/are involved with. The respondent was aloud to choose only one of the following categories: recreational, commercial, military, government, and research. This question was to be the basis for the remaining questions in the survey. The intent was to put how the respondent answered the remaining questions in context with the operational intent of the UAS they are involved with and draw conclusions.

Fifty-seven of the 58 respondents answered question 4. Thirty-one of the respondents indicated their involvement was recreational. Only 3 respondents selected commercial compared to 11 military, 6 government, and 6 research.

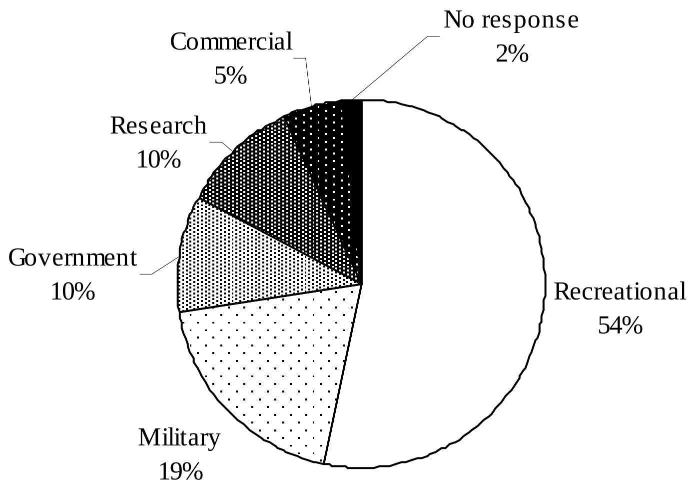

Figure 3. Respondent Involvement with UAS (Question 4)

Twenty-six of the 31 recreational respondents operate more than one UAS. Three of the six researchers indicated they are familiar with at least four UAS. Three of the six respondents that selected research in this question also selected research in question 1 to describe their involvement (not necessarily the same three as in the previous statement). Two of the three respondents that selected commercial responded to the training questions. Eight of the 11 that indicated military as the operational intent responded to the training questions. Nine of the recreational folks did not respond to the training questions.

Question 5 asked the respondents to describe the gross takeoff weight(s) of the UAS they are familiar with. Fifty-seven of the 58 respondents selected at least one range; 17 indicated more than one range. The ranges the respondents had to choose from were:

less than 5 pounds, 5 to 55 pounds, 56 to 250 pounds, 251 to 499 pounds, and 500 pounds or more.

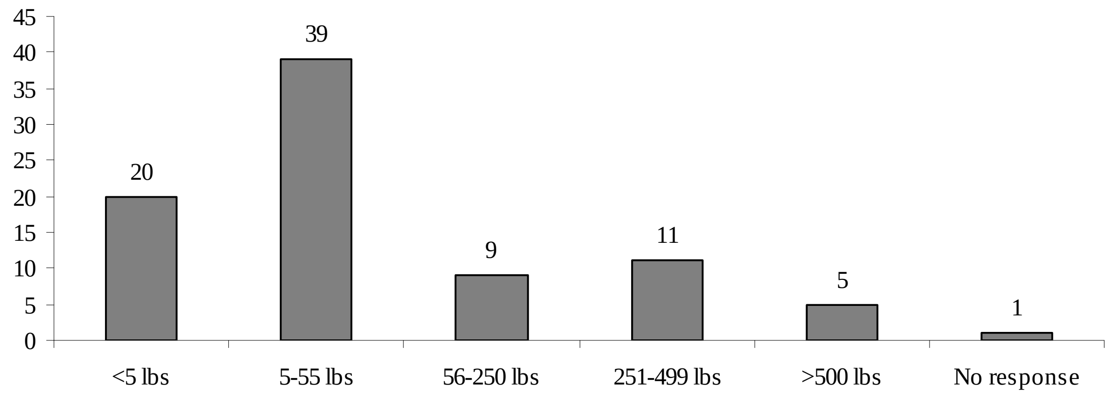

Figure 4. Respondent Familiarity with Various Sizes of UAS (Question 5)

There were 20 that responded they are familiar with UAS weighing less than 5 pounds. Of those 20, 18 indicated the sole operational intent is recreational. The other ones were government and military.

The most common range was the 5 to 55 pounds, which 39 indicated they are familiar. It can also be said of this group that all five operational intent areas specified in question four are represented in this group.

The next range was a much larger range, 56 to 250 pounds. Nine respondents indicated they are familiar with UAS in this range and all five operational intent areas from question 4 were also represented in this group.

Eleven checked the next category of 251 to 499 pounds. The final category was 500 pounds or more and 5 individuals indicated they are familiar/have experience with UAS of this size. All five in this category also selected another range therefore they are included in the results. Four of those 5 indicated the 5 to 55 pound range. The operational intent of these 5 was split between government (3) and military (2). All five of these respondents also responded to the training questions.

Looking at the group as a whole for question 5, 14 of the 57 respondents chose not to respond to the training questions. Thirteen of those 14 respondents indicated a UAS weight range of 55 pounds or less only; they did not indicate they had experience with anything weighing more than 55 pounds. That means, all but one (17 of 18) of the respondents who indicated experience with UAS weighing more than 55 pounds also responded to the training questions.

Question 6 asked the respondent to identify the highest operating altitude they have operated a UAS. The respondent was asked to select only one answer. Fifty-four of the 58 individuals responded. The ranges the respondent had to choose from were: less than 400 feet, 400 feet to 1,000 feet, above 1,000 feet to 18,000 feet, and above 18,000 feet. The totals for each of those ranges, respectively, were: 19, 14, 17, and 4.

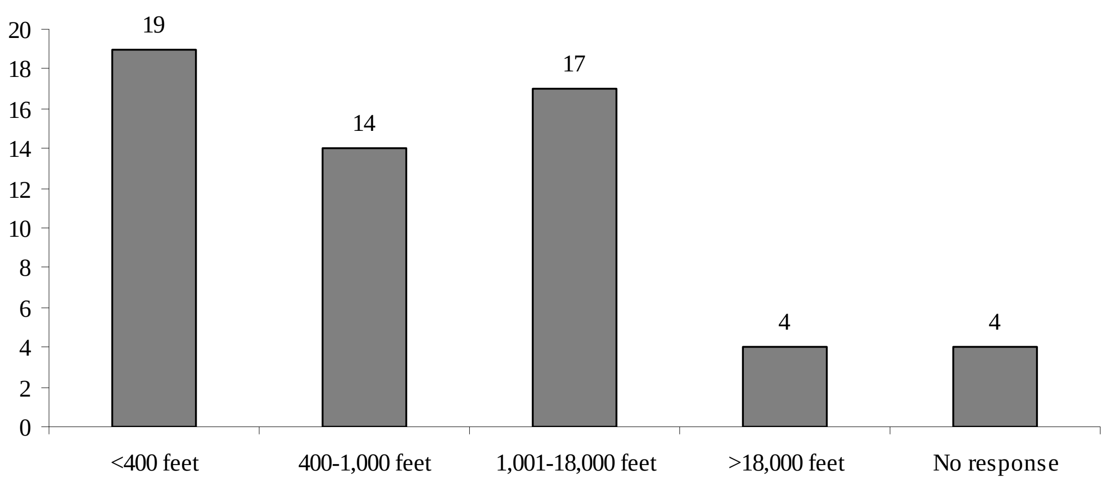

Figure 5. Highest Operating Altitude the Respondent has Operated a UAS (Question 6)

Of the 19 respondents that indicated the highest operating altitude was 400 feet or less for the smaller UAS they are familiar with, 17 indicated their operational intent was solely recreational. Eight of the 19 claimed to only have recreational experience with smaller UAS weighing less than 5 pounds and operating below 400 feet. Six of those eight did respond to the training questions. All either required an AMA membership or indicated no certificate was required. Those eight respondents also indicated they were self-trained.

Of the 14 individuals that responded operating above 400 feet to 1,000 feet, 8 are only involved recreationally and are operating smaller UAS weighing less than 55 pounds.

Question 7 asked the respondent to identify the airframe type(s) of smaller UAS they are familiar with. The respondents were provided four options to choose from: fixed-wing, rotary wing, lighter-than-air, and other. Of the 58 respondents, 56 chose to respond to this question; 14 respondents indicated more than one airframe type.

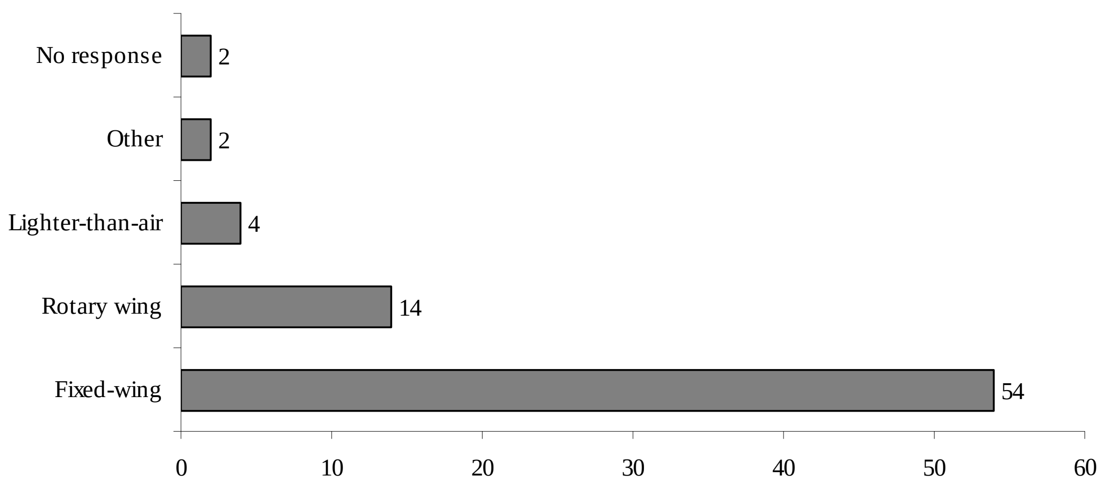

Figure 6. Respondent Familiarity with Various Airframe Types (Question 7)

An overwhelming majority (54) have experience with fixed-wing smaller UAS. Fourteen of the 56 indicated they were familiar with rotary wing aircraft; 13 of which are also familiar with fixed-wing UAS. Four respondents indicated they have experience with lighter-than-air smaller UAS. Those same four individuals also have experience with rotary wing and fixed-wing smaller UAS. Two individuals filled in the “other” category; one listed ornathopter and the other listed vectored thrust.

Question 8 asked what engine type the respondents had experience with. Fifty-six of the 58 respondents answered this question. The respondents were provided with four options to choose from: single-engine, twin-engine, lighter-than-air, and other. All 56 responded they have experience with single-engine smaller UAS. Fifteen individuals indicated they have experience with twin-engine smaller UAS. Only three of the four that answered lighter-than-air in question 7 also indicated lighter-than-air in question 8.

Question 9 captured the command and control type(s) the respondents had experience with. Specifically, the question asked whether or not the smaller UAS was operated with or without visual line-of-sight.

Fifty-five individuals provided a response with 10 responding more than once. Forty-seven individuals have experience with visual line-of-sight smaller UAS, 18 have experience with smaller UAS beyond visual line-of-site, and 10 respondents have experience with both visual line-of-sight and beyond visual line-of-sight smaller UAS.

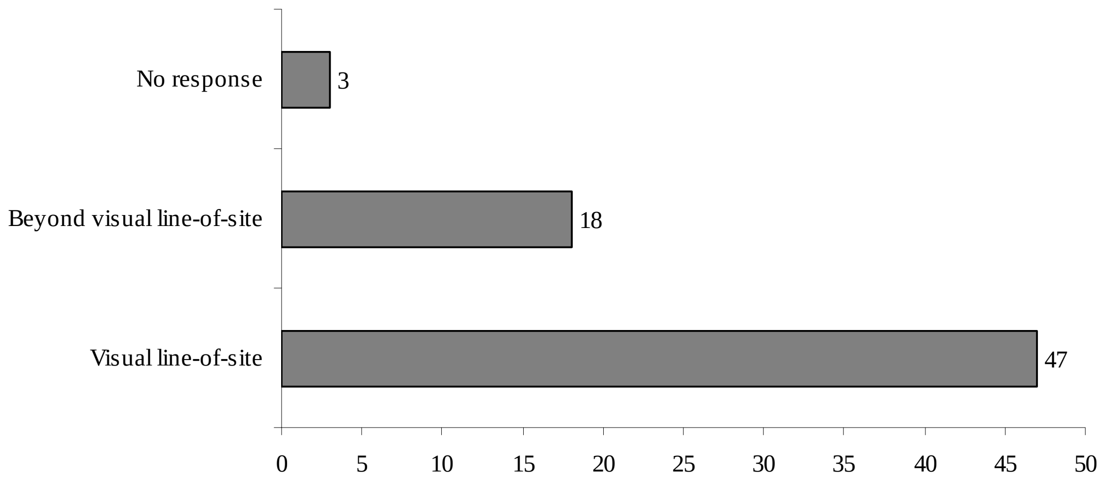

Figure 7. Command and Control Types of UAS (Question 9)

Of the 18 respondents indicating experience with smaller UAS beyond visual line-of-site, only 4 indicated they have experience with more than single-engine smaller UAS. There was quite a diverse response for beyond visual line-of-site operations: eight military, five government, three research, and two commercial operations. A majority (30) of the visual line-of-site operations are recreational operations.

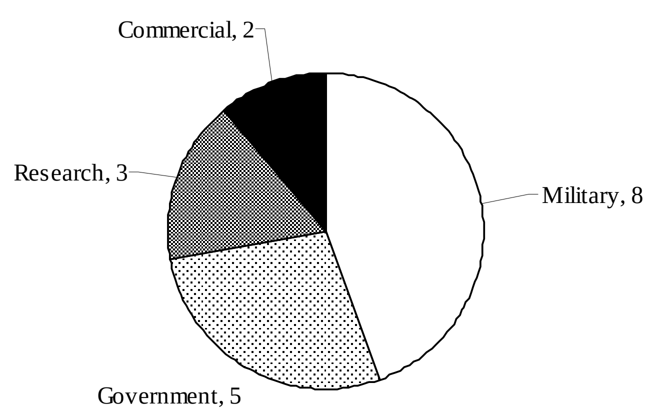

Figure 8. Operational Intent for Beyond Visual Line-of-site (Questions 4 and 9)

Question 10 asked the respondents to indicate all of the navigation types they have experience with. The options provided to the respondent included: manual control, pre-programmed waypoints with manual override, and pre-programmed waypoints without manual override.

Fifty-four individuals responded with 16 responding more than once. There were 47 responses for manual control, 22 responses for pre-programmed waypoints with manual override, and 5 responses for pre-programmed waypoints without manual override.

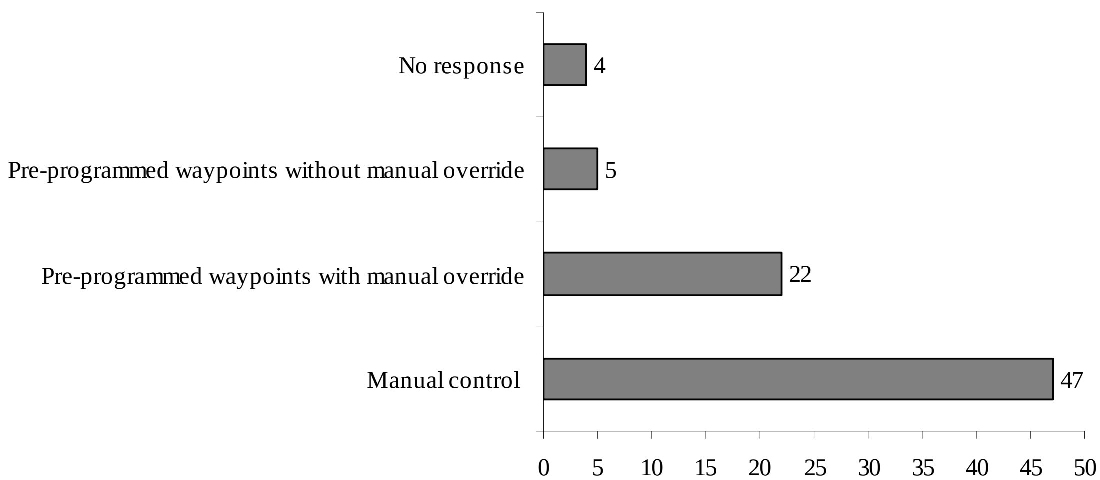

Figure 9. UAS Navigation Types (Question 10)

Of the 47 manual control responses, 30 are recreational operators. The remaining 17 responses were divided among the remaining categories: 5 government, 5 military, 3 commercial, 3 research, and 1 that did not respond to question 4 regarding operational intent. Also, 13 of the 47 respondents that indicated manual control also indicated experience with beyond visual-line-of-site UAS.

Of the 22 that indicated they have experience with pre-programmed waypoints with manual override, only 2 operate recreationally. Those same two also had selected visual line-of-site. The largest group in this category was military (9), followed by government (7), and research (4).

Of the five that responded they have experience with pre-programmed waypoints without manual override UAS, the operational intent for them was diverse: two were commercial, two were government, and one was military. Four of the five respondents selected both visual line-of-site and beyond visual line-of-site.

Question 11 asked what flight condition(s) the smaller UAS the respondent has experience with operates in. The respondent was provided with four choices: Day, Night, VMC, and IMC.

Fifty-six individuals chose to respond to this question with 49 selecting more than one option. An overwhelming majority of the respondents selected Day (53), 17 respondents selected Night, 38 respondents selected VMC, and only 8 respondents selected IMC.

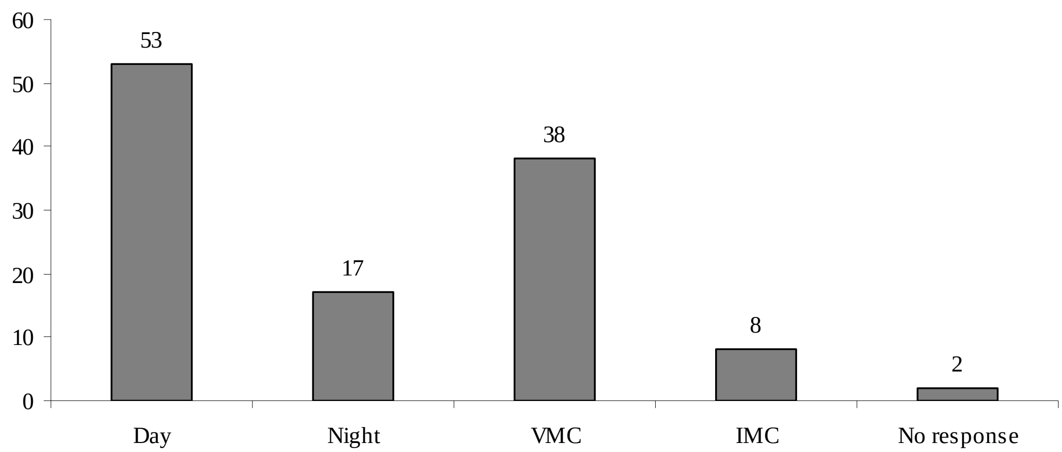

Figure 10. Flight Conditions (Question 11)

For all of those that selected Night, they all selected Day as well. Thirty-seven respondents selected both Day and VMC. Twenty-three of the 37 Day and/or VMC operations are recreational operations. There were 12 individuals that selected Day only, while only one individual selected VMC only. There were five respondents that selected all four choices. Of the eight that selected IMC as an operating condition, the operational intent of those flights, again, was diverse. There were three military, three government, one research, and one recreational.

Training Questions

Question 12 marked the beginning of the training questions. In total, 43 chose to respond, at least in part, to the training questions. Of those 15 that chose not to answer any of the training questions, 9 were recreational operations, 3 were military, 1 commercial, 1 government, and 1 non-response.

Question 12 asked the respondent to indicate what pilot certificate, if any, was necessary for the type of operation they were involved with. Of the 58 respondents, 43 chose to answer some or all of the training questions.

There were nine choices provided: student, sport, recreational, private, commercial, ATP, military, AMA membership, and none. A majority (23) indicated a pilot certificate was not necessary for the type of operation they are involved with. Only one selected recreational, and an additional individual selected private certificate. There were five that indicated a commercial certificate was required; four require a military certificate; and eight require an AMA membership.

Table 1. Pilot Certificate Required for Operation (Question 12)

Certificate	Number of responses
Student	0
Sport	0
Recreational	1
Private	1
Commercial	5
ATP	0
Military	4
AMA membership	8
Other	23

Of the 23 respondents who indicated no pilot certificate is required for the operation they are involved with, 61% indicated their operational intent was recreational. Those 14 individuals who operate recreationally also responded, at least in part, to the training questions.

Referencing the responses from question 4, the respondents that indicated their operational intent was research varied widely in the certificate required to accomplish that research. Of the six that indicated research, there was one recreational, one private, one commercial, two that indicated none was required, but one of those indicated the private pilot written was required by their COA, and one did not respond to this particular training question. The individual that did not respond to this particular training question only responded to the final 2 multiple-choice questions and indicated ‘not sure’ for both on how much time was spent in ground school and flight training.

There was not any consistency with the responses provided by the commercial, military, and government operations and each operational area had respondents that did not specifically answer this question. The certificates required for the commercial operation were a commercial certificate and no certificate. The certificates required for a military operation were: military, commercial, and no certificate. The certificates required for a government operation were a commercial or no certificate.

There were 19 respondents that indicated a certificate of some kind was necessary for their operation and each operational category was represented. Eight of the 19 respondents were recreational operations and all 8 indicated the AMA membership was what was required. In addition, the smaller UAS the 8 are involved with weigh 55 pounds or less and all operate below 1,000 feet with 75% operating at or below 400 feet.

Question 13 asked the respondents to indicate who provides the training for the smaller UAS they are involved with. The respondent could select more than one option. The options were: military, company-established, commercial training vendor, self-trained (no formal training), and other, which also provided a text box for a description. Again, 42 respondents chose to answer this question. The results showed 8 with military training, 10 with company-established training, 4 used a commercial-training vendor, 27 indicated they were self-trained, and 7 selected other.

Table 2. Smaller UAS Training Provider (Question 13)

Training Provider	Number of responses
Military	8
Company-established	10
Commercial training vendor	4
Self-trained	27
Other	7

Eight respondents indicated more than one. response Five of the eight military respondents indicated more than one option. Three self-trained also indicated another choice – one military, one company-established, and one commercial training vendor. For two of the respondents that indicated they received company-established training, they also indicated they received training from a commercial training vendor. When comparing the type of operation with who provides training, a commercial training vendor provided training for a government, a military, and a research operation.

When comparing the responses provided for the certificate required (question 12) and training received (question 13), there is a correlation between needing a certificate and having training. There were 11 respondents that indicated a certificate was required, not including those that indicated an AMA membership was required. Of those 11, 10 received training from the military, company-established training, and/or from a commercial training vendor.

When comparing the responses provided for weight of the smaller UAS (question 5) and the training received (question 13), 100% of the 10 respondents who received company-established training also selected the weight range of 5 to 55 pounds. Of those that indicated they received training from a commercial training vendor, 50% selected a weight of more than 55 pounds. When comparing those that responded they received company-established training, 90% operated at an altitude above 400 feet (question 6); there was one individual that did not respond to the altitude range question. Of the 9 that did respond, 78% operate at altitudes above 1,000 feet; only 22% indicated they operate above 18,000 feet. For those that received the training from a commercial training vendor, 100% operate above 400 feet; 75% above 1,000 feet.

Along those lines, of those that indicated they received training from the military, 100% indicated a weight range of greater than 55 pounds. Also, of those trained in the military, 88% indicated an operating altitude of greater than 1,000 feet.

Question 14 was a follow up to question 13. It asked if there was any testing given to the pilot to determine competency in flying the smaller UAS. Forty-two respondents answered the question. Seventeen indicated testing was given and 25 indicated no testing was conducted. There were two respondents that indicated testing was given to operate the smaller UAS, but they also responded they were self-trained.

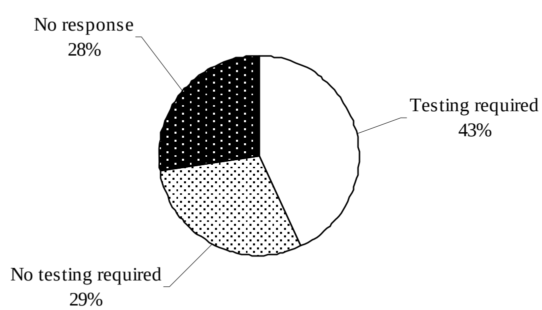

Figure 11. Pilot Testing to Operate a UAS (Question 14)

Of the 17 respondents that indicated testing was given, 5 indicated they operate recreationally. Four of the 17 operate at altitudes below 400 feet. Also, 4 of the 17 respondents operate a smaller UAS weighing less than 5 pounds; not necessarily the same 4 as those operating at altitudes below 400 feet. Eighty percent of those that indicated they had no testing were self-trained.

Question 15 asked the respondent to indicate which of the listed areas of operation are taught to pilots of the smaller UAS they are involved with. There were 10 areas of operation listed with an additional opportunity to write in comments. Of the 58 total respondents to the survey, 15 chose not to respond to any of the training questions. An additional six chose not to answer question 15; therefore, 37 respondents selected at least one option. Of the six, five indicated no certificate was required or only an AMA membership was required and they were self-trained (1 NR – research). The most common selections for training received were takeoff/launch and landing/retrieval/recovery. The least common selection was crew resource management.

Table 3. Smaller UAS Training Areas of Operation (Question 15)

Area of Operation	Number of responses
Takeoff/launch	35
Landing/retrieval/recovery	35
Taxi	24
Climbs/descents	34
Turns	35
Stalls/spins	21
Emergency procedures/system malfunctions	26
Remote control/ground control station	30
Aerodynamics	20
Crew resource management	11

Referencing the responses to question 1, 14 respondents indicated they provide training for R/C aircraft and/or smaller UAS; 10 of which responded to this training question. All 10 indicated they provided training in the following operational areas: takeoff/launch, landing/retrieval/recovery, climbs/descents, turns, and emergency procedures/system malfunctions. Eighty percent provided training in aerodynamics and 90% provided training in remote control/ground station operation and CRM. Only 50% provided training in taxi and stalls/spins.

Four of the 10 respondents that provide training also provided additional comments; the only additional comments received. The other areas of training they provided included: aircraft systems, regulations, observer training, safety, emplacement/deplacement of the ground control equipment, basic maintenance, airspace rules and regulations, and airspace management.

Question 16 asked the respondents to indicate if the information taught was general information and could be applied to operating most smaller UAS or if the information was type-specific and applicable to only one type of smaller UAS. There were 37 respondents that also answered this question; 15 did not respond to any training questions and 6 chose not to answer this particular training question, but responded to other training questions. Of the six, four indicated their operational intent was recreational, no certificate was required or only an AMA membership was required, and they were self-trained (1 military, 1 NR - research).

Twelve respondents indicated they received general information only; 3 received type-specific only training; and 22 respondents received both general and type-specific training. For the respondents involved in training (question 1), 80% answered both general and type-specific training are provided/received.

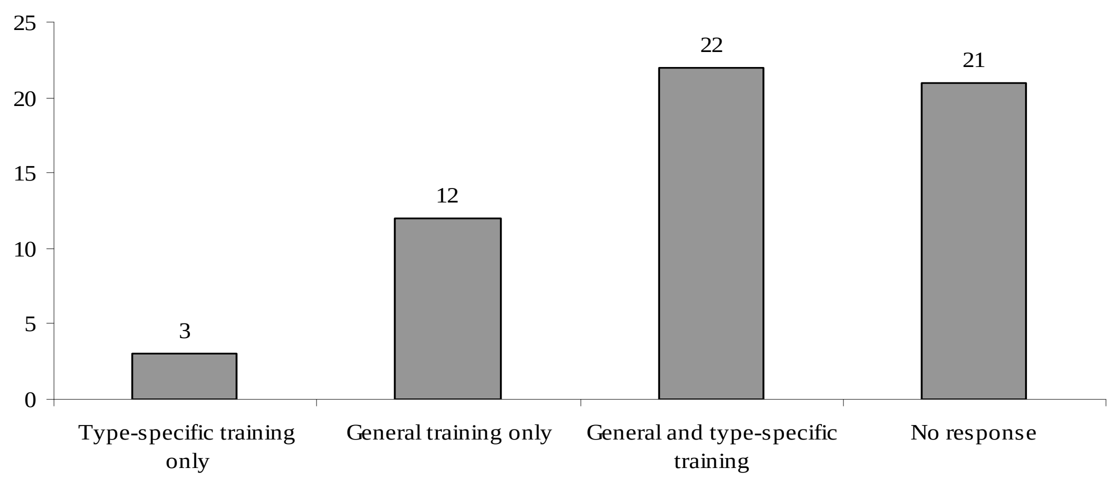

Figure 12. Type of UAS Training Received (Question 16)

Question 17 asked the respondents to indicate how much time, if any, was spent in ground school or classroom training. While typical aeronautical knowledge sections of aviation pilot certification regulations (14 CFR part 61) do not usually specify a minimum amount of time to be spent in ground school, this question was designed to capture if there was any ground school or classroom training being provided to pilots of smaller UAS; and, if so, how much time is spent.

Table 4. Time Spent in Ground School or Classroom Training (Question 17)

Hours	Number of responses
None	17
1 – 5 hours	6
6 – 10 hours	2
11 – 15 hours	1
16 – 20 hours	0
21+ hours	4
Varies with experience	9
Not sure	3

Question 18 asked the respondents to indicate how much time, if any, was spent in flight training and/or testing a pilot. In aviation pilot certification regulations (14 CFR part 61) there is typically a minimum hour requirement before an applicant can apply for a certificate. This question was designed to gauge how much time is being spent conducting flight training absent federal regulations.

Table 5. Time Spent Flight Training and/or Testing (Question 18)

Hours	Number of responses
None	12
1 – 5 hours	8
6 – 10 hours	4
11 – 15 hours	0
16 – 20 hours	0
21+ hours	6
Varies with experience	10
Not sure	2

Question 19 asked the respondent, in his/her opinion, to describe general operating characteristics (can be used to operate multiple UAs or R/C aircraft of similar design) pilots need to be taught to operate the smaller UAS he/she was/are involved with. Out of the 58 respondents, 27 responded to this question; 9 training respondents responded to the opinion questions. A few of the common themes were: basic aerodynamics, situational awareness, takeoff and landing, and computer skills. A complete summary of the comments provided can be found in Appendix B.

Question 20 asked the respondent, in his/her opinion, to describe the type-specific operating characteristics that need special emphasis in pilot training that pilots need to be taught to operate the smaller UAS he/she was/are involved with. Out of 58 respondents, 26 responded to this question; 9 were training respondents. Many of the same ideas and suggestions shared in question 19 were also suggested in question 20. However, there were some additional knowledge and skill areas listed that should be mentioned. They included: speed and control response for the varying sizes and performance capabilities of UAS, emergency procedures, and maintenance techniques. A summary of the comments provided can also be found in Appendix B.

CHAPTER IV

DISCUSSION

Questions about the Respondent

The survey tool intended to capture what physical flying skills were necessary to operate UAs as well as determine if knowledge of aerodynamics was necessary for UA operations. The UAS industry is still relatively small, yet the receipt of 80 completed surveys exceeded expectations. The 17 responses from individuals outside of the U.S. also exceeded expectations. While there is a lot of work globally on developing the infrastructure to handle UAS operations, a majority of it is centralized in the U.S. The quality of the information in the responses appears genuine and conveys a wide range of UAS experience.

Every operational category (recreational, commercial, military, government, and research) was represented, with UAS pilots representing the largest category of involvement. The range of responses demonstrates the diversity of the UA flying population and the consideration that will have to be given when developing the rule requirements for training and certification of UA pilots. This research is foundational and could provide the ground work for future UA research in training and certification as well as NAS integration.

It is noted that roughly 20 percent of the respondents that indicated their involvement with UAS was as a pilot did not respond to the training questions. A reasonable assumption for not responding is they did not have any information to provide given nearly all of them indicated their primary involvement behind their operations was recreational. Currently there are no FAA training or certification requirements for operating model aircraft in the NAS; only the AC that provides guidance.

Of those respondents that indicated familiarity with smaller UAS training, they also selected another category of knowledge and/or involvement with smaller UAS. For most (11/14), that other selection was pilot. This overlap is reasonable considering those that provide flight training in manned aircraft are also pilots.

Question 3 provided a sense for the variety of types of UAS individuals may be involved with. Given the respondents that indicated more than one type of UAS (42) compared to the number of respondents that had formal training, it appears there should be a basic set of knowledge and skills for operating smaller UAS that can be transferred from one type to another with little or no additional training.

The respondents were asked to describe the operational intent of their involvement with UAS in question 4. Drawing from what is known regarding manned aircraft flight training, the type of operation might be considered indicative of the level or structure of training one might receive. For example, recreational involvement is more likely to have less structured training than a commercial or military operation. Given the overall responses to the questions, the comparison between the type of operation and the type of training received appears to hold true.

Those respondents that are solely involved in UAS recreationally generally have had no formal training or were self-trained. This conclusion was drawn in part by the lack of response to the training questions as a whole. The other part is the FAA does not require any formal training or certify UAS operators at this time; therefore, structured training could not be expected. That said, there is an extensive "tribal knowledge" base that recreational flyers draw from that could be categorized as informal training. That knowledge could be very beneficial to the FAA going forward in the development of training and certification regulations.

In comparison, all respondents involved commercially or in the military with UAS had some kind of formal training. It is also important to note that while there was no consistency in the amount of manned aircraft training a UAS pilot should have, there is a perceived benefit by current operators to having knowledge and experience with manned aircraft based on the requirements UAS pilots are facing for employment.

The FAA knowledge tests, which some UA pilots are taking as a requirement for employment, could be argued to provide a good foundational knowledge of the U.S. NAS. Topics that would be covered include airspace, ATC communications, aviation regulations, and basic aerodynamics. A UAS pilot that intends to operate in the U.S. NAS could benefit significantly by having this foundation.

Another general conclusion that could be drawn from the data received is as the weight of the UAS increases, the need for training also increases. There were 32 respondents that indicated the operational intent for a UAS weighing 55 pounds or less was recreational. When comparing how those 32 respondents answered the training questions, 10 did not respond and the remaining 22 indicated they had not received any formal UA training. Above 55 pounds, 17 of the 18 respondents provided input for the training questions and contributed more than ‘self-trained’. The responses for each of the weight ranges was very diverse giving additional credence to the conclusion that the operational environment is very diverse and developing rules and regulations to accommodate that will be challenging.

Question 6 is an important question to analyze how the altitudes for operating UAS compare with the type of operation. This question was designed to gauge how many people are operating at altitudes that may also involve manned aircraft operations as well as air traffic control services in the future.

The responses for operations at altitudes less than 400 feet were primarily recreational, which was expected given the existing guidance for recreational operators. Of particular interest is the 400 feet to 1,000 feet category. Eight of the 14 individuals that indicated this category as the highest altitude they operated in were recreational only operators and operating smaller UAS weighing less than 55 pounds. Only three were recreational operators in the 1,000 feet to 18,000 feet category that operated UAS smaller than 55 pounds. These recreational operators are operating outside of the guidance provided by the AC and the AMA safety code and may be the most impacted by a rule change that would now regulate their operations with smaller UAS.

Questions 7, 8, 9, and 10 were designed to capture the types and sophistication of UAS currently being operated to determine if there was any common ground among those operating smaller UAS. Responses to these questions assisted in providing perspective when comparing the responses to the training questions. Specifically, the questions focused on the respondents experience with a UAS category, engine type, control type, and navigation type.

The data indicated that nearly all are familiar with fixed-wing UAS, but there were individuals who also had experience with rotary wing and lighter-than-air UAS. The two additional comments written in were ornathopter and vectored thrust. This added dynamic of different categories presents another challenge for the FAA in designing a certification and training structure.

All of the respondents to question 8 indicated they were familiar with single-engine UAS. In addition, more than 25% indicated they were also familiar with twin-engine UAS and a few were familiar with lighter-than-air UAS. Common ground was established with this question; everyone has a single-engine UAS foundation. Though the single-engine UAS may not necessarily have been the first exposure for the respondent, in most cases we can assume it was.

Beyond visual line-of-sight is one of the most challenging components to UAS integration into the NAS because of the relationship it has to see-and-avoid. See-and-avoid is a critical component to manned aircraft operations in the NAS and one of the major barriers to entry for UAS. Eighty-five percent of the respondents are familiar with visual line-of sight; most of which were recreational operations. Visual line-of-sight operations are more capable of see-and-avoid because the pilot or observer is to maintain a visual on their UAS at all times. That said, because they are on the ground, the spatial orientation of their UAS compared to other aircraft may be difficult to determine, especially as the altitude increases. Defining an altitude limit for operating recreationally without regulation will be necessary. The type of operation for respondents that indicated they have experience with beyond visual line-of-sight operations was not recreational. The respondent experience was military, government, research, or commercial operations.

The navigation types, or types of operational control, are also an important component for regulators to understand. Not surprisingly, the most common type of navigation was manual control; but 40 percent of the respondents indicated experience with pre-programmed waypoints with manual override and 9 percent with pre-programmed waypoints without manual override. Part of the safety risk assessment for UAS in the NAS will be defining how diversions and emergency situations will be handled from both an operator point-of-view and from an air traffic point-of-view. Loss of communications or data-link capability on a UAS that does not have manual override capability is a significant issue that will need to be solved prior to NAS integration.

Question 11 was designed to assess the operating environment for the smaller UAS. Eighty-seven percent selected more than one option; the most popular was day operations. It was anticipated the number of respondents for day to be the same as the number of respondents for VMC, but that was not the case. VMC was not defined in the survey tool and it is possible there were respondents who were not familiar with that acronym, especially respondents who do not hold an FAA or military pilot certificate. IMC was also not defined, but it was anticipated this would be one of the minority categories. There was representation from military, government, and research operations; but one recreational operator also indicated IMC, which seems like an outlier.

Training Questions

The training questions were designed to collect basic information about the level of training required to operate a UAS and the type of information and skill that is trained. FAA pilot certification in manned aircraft is divided into two areas: aeronautical knowledge and aeronautical experience. One would assume the FAA will attempt to mirror the existing structure when developing the UAS pilot certification regulations.

There will be a number of similar aeronautical knowledge areas that will likely be listed for a UAS pilot certificate given the environment in which they will operate will be the same as that of manned aircraft. This research was specifically interested in aerodynamic knowledge and whether or not it is necessary for a UAS pilot to understand these basics. The data collected in this survey indicates some basic understanding of aerodynamics should be required at some levels, but necessarily all levels.

There will also be a number of similar aeronautical experience areas that will likely be listed for a UAS pilot license. This research referenced current aeronautical experience areas to be trained for a manned aircraft as well as the RTCA SC-203 recommendations for UAS training when developing the areas listed to be trained. The data collected in this survey indicates that most areas, if not all, should also be trained to some level.

Nearly 75% of the respondents chose to respond, at least in part, to the training questions. Of those that chose not to respond, 60% were recreational operators. It is likely that these respondents received no training for their operations, or were self-trained, and no pilot certificate was required for their operations. The remaining 40% were made up of military, commercial, and government operators.

Of those respondents that did respond to the training questions, 25% had indicated they were involved in training smaller UAS. Receiving information from individuals who train other smaller UAS pilots is important and arguably more valuable. Those respondents involved in smaller UAS training represented all operational intent categories, all weight ranges, and all altitude ranges. All airframe types, engine types, navigation types, and flight conditions were also represented by those involved in UAS training.

Question 12 asked the respondent to indicate what pilot certificate, if any, was necessary for the type of operation they were involved with to provide insight into the level of manned aircraft training the respondent has as well as what type of background people in this industry find appropriate for smaller UAS operations. In addition, question 13 asked who provided the smaller UAS training, if training was provided.

It is pretty difficult to draw any conclusions from the certification question based on the responses received. There were only 19 respondents that indicated a certificate of some kind was necessary for their operation though each operational category was represented. Eight of the 19 respondents were recreational operations and all 8 indicated the AMA membership was what was required. There was not any consistency with the responses provided by the commercial, military, and government operations and each area had respondents that did not specifically answer this question.

When reviewing who provided smaller UAS training, there also didn’t appear to be a consistent response, with the exception of those that indicated they were self-trained or received no formal training. However, there did seem to be a correlation between those operations that required a pilot certificate and those that received training for their smaller UAS operation. There were 11 respondents that indicated a pilot certificate was required, not including those that indicated an AMA membership was required. Of those 11, 10 received training from the military, company-established training, and/or from a commercial training vendor.

When comparing the responses provided for weight of the smaller UAS (question 5) and the training received (question 13), 100% of the 10 respondents who received company-established training also selected the weight range of 5 to 55 pounds. Nine of those 10 respondents also indicated they operate above 400 feet with most operating above 1,000 feet (question 6). The military-trained respondents primarily operate smaller UAS above 55 pounds and above 1,000 feet. Based on the training responses and the comparisons made to responses received to other questions, a conclusion can be drawn that some level of training should be required for a non-recreational operation.

Question 14 was a follow up to question 13 asking if any testing is given to the pilot to determine competency in flying the smaller UAS. While there were a few responses from recreational operators that indicated testing was given, testing of the non-recreational operations is of more significance. Only 81 percent of those that received training from the military, a commercial training vendor, and/or through company-established training indicated that testing was conducted for operating smaller UAS.

Question 15 was a key question in the survey and 37 of the 43 respondents that answered at least some of the training questions responded to this question. Five of the six that did not respond indicated no certificate was required or an AMA membership was required. A list of operational areas for training was provided and the respondent was to select all areas that they received training.

The most common selections for training received were takeoff/launch, turns, and landing/retrieval/recovery; 35 of the 37 respondents indicated training received in these areas. Climbs/descents were also selected by most with 34 respondents indicating training received. This was not a surprise given all four areas are applicable to every operation. There were a couple areas of operation that would not necessarily apply to every operation depending on the type of UAS being trained and the type of operation. Those categories included: taxi and crew resource management (CRM). The least common selection was CRM with only 11; 24 indicated receiving training on taxiing.

Of the remaining categories, remote control/ground control station training was received by 30 of the respondents and emergency procedures/system malfunctions training was received by 26 of the respondents. Surprisingly only 21 received training on stalls/spins and 20 received training on aerodynamics. Given the importance of these areas in operating manned aircraft, one would have expected these categories to have a higher level of training. That said, more than half of those that responded to the training questions indicated they received this training demonstrating there currently is a perceived value in it in some cases.

It is important to note that of the 10 respondents that indicated they provide training for R/C aircraft and/or smaller UAS, all 10 indicated they provided training in the following operational areas: takeoff/launch, landing/retrieval/recovery, climbs/descents, turns, and emergency procedures/system malfunctions. Eighty percent provided training in aerodynamics and 90% provided training in remote control/ground station operation and CRM. Only 50% provided training in taxi and stalls/spins. A more structured training program sees value in training most of the areas of operation listed.

When evaluating the type of training being taught, it is important to capture what is basic information and what is type-specific information. Nearly all of the individuals that responded to the training questions received what they considered to be basic information for operating smaller UAS. Nearly two-thirds of them also received type-specific training. This information is important to a regulator when developing the pilot certification structure. The current FAA pilot certification structure may not be appropriate for UAS. However, the typical certification structure combined with the sport pilot structure may be something to consider.

Sport pilot has a number of similar features in its structure compared to the traditional structure, but what’s unique is there are endorsements for the different types of sport aircraft being flown. Understanding that sport pilot is a lesser certificate compared to a private pilot certificate because of the restrictions on the sophistication of the light sport aircraft and the environment the sport pilot is allowed to operate in, the structure may be applicable to UAs that are currently operated as R/C aircraft and/or recreational aircraft. If there was an established categorization of UAs, possibly grouped together based on weight, performance, and/or operating altitude, utilizing endorsements on UA pilot certificates may be an option. There may still be a private, commercial, and ATP certificate with new stipulations on how to obtain UA privileges, but an endorsement system may be necessary to accommodate the wide-ranging variation and sophistication of UAs operated. This concept is very broad in nature, but could be a starting point for regulators.

Questions 17 and 18 were focused on the amount of time spent in training, both in ground school or classroom training and flight training and checking. While typical aeronautical knowledge sections of the pilot certification regulations do not usually specify a minimum amount of time to be spent in ground school, question 17 was designed to capture how much time is spent, if any. There are minimum hour flight experience requirements before an applicant can apply for a pilot certificate. Question18 was designed to gauge how much time is being spent flight training and checking absent federal regulations. Twenty-two respondents indicated time in ground school training was conducted compared to 28 respondents that indicated time spent flight training. In both cases, if a specific range was selected, the time was less than 10 hours or more than 20 hours and nothing in between. What was most interesting was the number of respondents indicating the amount of training varied with experience.

Questions 19 and 20 were opinion questions which allowed for the respondent to provide his or her thoughts on smaller UAS training. Less than half of the 58 respondents provided comments here. Of those that did respond, a third indicated they were involved in smaller UAS training. A few of the common themes for general operational information were: basic aerodynamics, situational awareness, takeoff and landing, and computer skills. Many of these same ideas and suggestions were also found in the type-specific training themes. They included: speed and control response for the varying sizes and performance capabilities of UAS, emergency procedures, and maintenance techniques.

Some of the additional items identified by the respondents involved with training include: aircraft systems, regulations, observer training, safety, emplacement/deplacement of the ground control equipment, basic maintenance, airspace rules and regulations, and airspace management.

Summary

Civil and commercial UAS operations continues to be an emerging industry and more needs to be learned with future research. There appears to be a significant amount of research focusing on the operation of larger UAs, like the Predator, but little focusing on the operation of smaller UAs. While the research for the larger UAs is necessary, the FAA's rulemaking initiative is focused on small UAs and will impact operations that have not been regulated previously. Collecting additional data on small UAs will likely be part of the FAA's focus with its rulemaking and important information was gained through this research that will be helpful with its initiative.

Based on the evaluation of the data in this research, it has provided some validity to the operational best practices developed by RTCA SC-203. For pilots operating UAs weighing less than 5 pounds and below 400 feet, there does not appear to be a need to require any specific training and they could continue to operate in those conditions with minimal risk to the NAS and the population. For UAs weighing 5 pounds or more and operating above 400 feet, they should be regulated and pilots should obtain some kind of pilot certificate or operating privilege to operate in the NAS.

Going forward, it would be beneficial for future research to look at why certain areas of operation are not always trained, how much time is spent learning specific tasks or in specific operational areas, defining what experience a UAS pilot could have that could mitigate the amount of training time required to be qualified to operate a UAS, and obtaining additional details surrounding the testing and/or checking of a UAS pilot.

Should the FAA decide to issue UAS operators or pilots some kind of pilot certificate or authorization, building a UAS pilot certification structure will be no easy task. If an approach, similar to what was done with light sport aircraft, were to be considered, the UAS industry would need to agree on some kind of categorizing for the UAs that would enable an endorsement-like system, at least for the smaller UAs, to accommodate the variety of UAs currently operating. Because of the disparity and varying operation between UAS operations, determining where the dividing line is for recreational operations will be critical as the industry moves forward.

APPENDICES

Appendix A

Final Survey Questions

I. About the Respondent

1. Please select the option(s) that best describes your involvement, past or present, with smaller unmanned aircraft systems (i.e. an unmanned aircraft (UA) or remote controlled (R/C) aircraft weighing less than 500 pounds)?

   Please check ALL that apply:
   - Manufacturer (design and/or produce UAs or R/C aircraft)
   - Operator (company that operates UAs or R/C aircraft)
   - Researcher (utilize UAs or R/C aircraft to conduct research)
   - Pilot (fly and/or operate UAs or R/C aircraft)
   - Training (provide training for pilots operating UAs or R/C aircraft)
   - Other (please describe)

2. Is your past or present involvement, as indicated in question 1, with UAs or R/C aircraft based on experience in the United States?
   - Yes
   - No

3. How many smaller unmanned aircraft system(s) models (i.e. UAs or R/C aircraft weighing less than 500 pounds) do you, or the entity you represent, have experience with?
   - 1
   - 2
   - 3
   - 4 or more
   - Prefer not to disclose

4. Which option best describes the operational intent of the smaller unmanned aircraft system(s) you were/are involved with?

   Please check ONLY one:
   - Recreational
   - Commercial
   - Military
   - Government (non-military)
   - Research

Note: Please answer the remaining multiple choice questions based on your response to #4.

5. Please select the range that best describes the gross takeoff weight(s) of the smaller unmanned aircraft you were/are involved with.

    Please check ALL that apply:
    - Less than 5 lbs
    - 5 lbs – 55 lbs
    - 56 lbs – 250 lbs
    - 251 lbs – 499 lbs
    - 500 lbs or more

6. Please select the <u>highest</u> operating altitude of a smaller unmanned aircraft weighing less than 500 pounds that you were/are involved with.

    Please check ONLY one:
    - Less than 400 feet
    - 401 feet to 1000 feet
    - 1001 feet to 18000 feet
    - Above 18000 feet

7. What airframe type(s) of smaller unmanned aircraft systems were/are you involved with?

    Please check ALL that apply:
    - Fixed wing
    - Rotary wing
    - Lighter-than-air
    - Other (please describe)

8. What engine type(s) of smaller unmanned aircraft systems were/are you involved with?

    Please check ALL that apply:
    - Single engine
    - Twin engine
    - Lighter-than-air
    - Other (please describe)

9. What command and control type(s) of smaller unmanned aircraft systems were/are you involved with?

    Please check ALL that apply:
    - Visual line-of-sight
    - Beyond visual line-of-sight

10. What navigation type(s) of smaller unmanned aircraft systems were/are you involved with?

    Please check ALL that apply:
    - Manual control
    - Pre-programmed waypoints with manual override
    - Pre-programmed waypoints without manual override

11. What flight condition(s) do the smaller unmanned aircraft system(s) you were/are involved with operate in?

    Please check ALL that apply:
    - Day
    - Night
    - VMC (visual meteorological conditions)
    - IMC (instrument meteorological conditions)

II. Training questions

12. What is the minimum pilot certificate necessary, if any, for operating the smaller unmanned aircraft you were/are involved with?
    - Student
    - Sport
    - Recreational
    - Private
    - Commercial
    - ATP
    - Military
    - Academy of Model Aeronautics Membership
    - None
    - Other (specify)

13. For the smaller unmanned aircraft system(s) you were/are involved with, please describe who provides the pilot training (i.e. ground school, flight training, etc.).

    Please check ALL that apply:
    - Military
    - Company-established
    - Commercial training vendor
    - Self-trained (no formal training)
    - Other (please describe)

14. For the smaller unmanned aircraft system(s) you were/are involved with, is there any testing given to the pilot to determine competency for flying it?
    - Yes
    - No

15. For the smaller unmanned aircraft system(s) you were/are involved with, please describe which of the following areas of operation are taught to the pilots.

    Please check ALL that apply:
    - Takeoff/launch
    - Landing/retrieval/recovery
    - Taxi
    - Climbs/descents
    - Turns
    - Stalls/spins
    - Emergency procedures/system malfunctions
    - Remote control/ground station operation
    - Aerodynamics
    - Crew Resource Management (CRM)
    - Other (please specify)

16. Is the information taught general or type-specific?
    - General only
    - Type-specific only
    - General and type-specific

17. How much time was/is spent, if any, in ground school or classroom training?
    - No ground school or classroom training
    - 1 – 5 hours
    - 6 – 10 hours
    - 11 – 15 hours
    - 16 – 20 hours
    - 21 or more hours
    - Varies with experience
    - Not sure

18. How much time was/is spent, if any, in flight training and/or testing a pilot?
    - No flight training/testing
    - 1 – 5 hours
    - 6 – 10 hours
    - 11 – 15 hours
    - 16 – 20 hours
    - 21 or more hours
    - Varies with experience
    - Not sure

19. In your opinion, what are the general operating characteristics (can be used to operate multiple UAs or R/C aircraft of similar design) that pilots need to be taught to operate the smaller unmanned aircraft system(s) you were/are involved with?
    - Free-form text box

20. In your opinion, what are the type-specific skills that need special emphasis in pilot training for the smaller unmanned aircraft system(s) you were/are involved with?
    - Free-form text box

Appendix B

Response Summary (Question 19)

General Operating Knowledge and Skills	**Number of Respondents**
Emergency /backup /relief procedures	10
Basic aerodynamics	8
Situational awareness (orientation b/n pilot and UA for line-of-site; differences b/n manned and UAS; location of other a/c)	8
Basic operating procedures (safety; airspeed and fuel management)	8
Phases of flight (ground, takeoff, maneuvers, landing, etc.)	8
Performance/propulsion (slow flight; operational limitations; weight & balance; CG)	6
Knowledge of airspace	6
Computer-based training (Realflight 5) and/or have computer skills	4
Stall/spin/loss of control	4
Pilot's license (beyond visual line-of-site experience); some actual flight experience	3
Communications in the NAS	3
Knowledge of systems (UA; electronic; ground control station; communications/radios)	3
Crew resource management	2
Risk assessment	2
R/C skills / control sensitivity for R/C	2
Knowledge of part 91 flight rules	2
Maintenance procedures	1
Trim techniques	1
"None"	1
Other – safety pilot level of skill dependent on scale and airspace (2) start with a training UA employment of the payload best practices selecting appropriate UA COA information	7

Response Summary (Question 20)

General Operating Knowledge and Skills	**Number of Respondents**
Emergency procedures/backup procedures/ lost communications	7
Operational procedures/ techniques (fuel, start, flight checks, radio, battery; service bulletins and tech advisories)	5
Situational awareness/ separation of pilot and aircraft	4
Performance/propulsion (slow flight; operational limitations; weight & balance; CG)	4
Safety	3
Control sensitivity for R/C aircraft/ roll and pitch rate	3
Airspace comprehension	3
Aerodynamics	3
“See above”	3
“None”	3
Aircraft systems	2
Stall/spin recovery	2
Maneuvering	2
Repair/maintenance	2
Regulatory knowledge	2
Three-dimension visualization & instrument reading	1
Ground and flight characteristics – model specific	1
Computer skills	1
Other – Anything that deviates from what is obvious to the person from their previous experience “See Item 8 above” Landing with a forward looking tv Profiles and standard operating procedures	4

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