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Integrating Unmanned Aircraft Systems into the National Airspace System

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Currently there is a lot of interest in integrating unmanned aircraft systems (UASs) into the national airspace system (NAS). Well-established processes are currently in place to certify all aspects of the design, operation, training, and maintenance of the aircraft now in the NAS. The FAA is drawing on these experiences and processes to develop certification criteria for UASs as there are requests for them to enter the NAS. It is important to identify the differences between manned aircraft and unmanned aircraft systems and how those differences will impact operations in the NAS. As these differences are addressed, all users that will impacted in the system should be considered, as well as the infrastructure of the certification processes and regulatory requirements. Operations in the National Airspace System will inevitably change with the introduction of UASs. As an industry, we must utilize established processes and current tools to work together to successfully adapt to these emerging technologies.

Introduction

New challenges are becoming apparent as the FAA begins to integrate Unmanned Aircraft Systems (UASs) into the National Airspace System (NAS). Existing certification criteria for manned aircraft may be adapted to address the inherent physical and operational differences between manned and unmanned aircraft. This must be accomplished so that the overall level of safety and efficiency in the NAS is not compromised. The FAA is actively evaluating current regulations and determining how and when to develop a new set of requirements for the design and operation of UASs. To do this they are drawing on the well-established processes currently utilized to evaluate and certify manned aircraft.

Integrating UASs into the NAS means that these vehicles will need to meet the requirements for design, operation, and training met by all other participants in the NAS. In the United States each of these elements (design, operations, training, and maintenance) must be approved through the appropriate certification processes and maintained to the regulatory requirements. The UASs are significantly different in design and operations from the aircraft and operations currently participating in the NAS and these pose many questions and challenges to be met before the integration can happen. Even the language we use for some situations does not apply when UASs are put into the scope of operations. The purpose of this paper is to describe these questions and challenges and discuss what is being done to address them. The following will address the changes that will occur in the NAS as UASs are introduced and the challenges with certification process and requirements. Certification must be accomplished for design, training, operations, and maintenance. These all have their unique challenges; however, we will focus mostly on design certification.

The term "UAS" was adopted by the FAA to include all aircraft that operate without "direct intervention with or on the aircraft" (RTCA SC-203, 2006). It is important to understand that the term 'system' encompasses the vehicle, the control station, and the interaction between the two. Regulations for design and operations must consider all of these components. The most significant unique feature of the UAS is the often distributed nature of command, control, and communication; these must all be accomplished through some sort of data link either directly with the aircraft or through a satellite.

Implications for the NAS

Figure 1 depicts the current communication link structure typical in the NAS today: air traffic control and the operating organization or company can communicate directly with the pilots in the airplane and possibly with the systems on board the airplane through data link technology. Figure 2 depicts the much more complicated communication links required by the UAS: air traffic, company, and the pilots in the control station sometimes must go through a satellite link to communicate with the airplane. These additional links naturally increase the latency of such communications with the airplane systems and between air traffic control and the pilots. The definition of the maximum latency that can be allowed for different communication links to maintain the current level of safety in the NAS is still being addressed and defined.

The technological complexity is not the only multi-component aspect that must be addressed when considering the introduction of UASs in the NAS. For human factors issues we need to consider all users in the system and their implications and requirements during this transition. Table 1 includes most of the users in the system that should be considered. Each has a unique contribution and perspective of the overall system and the safety implications that could result from including UASs.

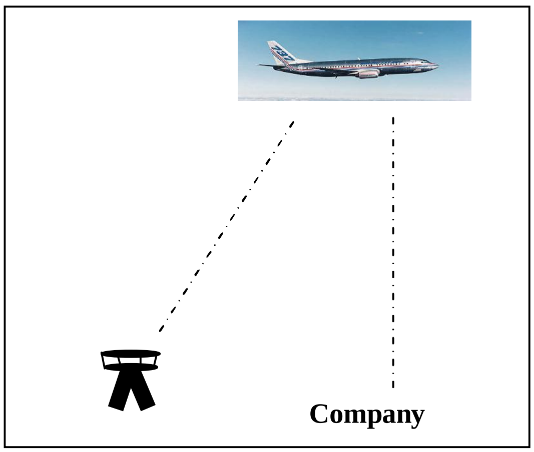

Figure 1. Current National Airspace System and communication links.

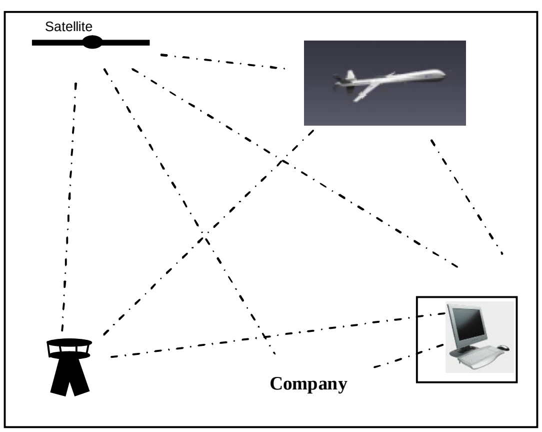

Figure 2. National Airspace System including UAS and all communication links required.

Some other differences of UASs compared to airplanes that are now in the NAS that must be considered are the separation of pilot and airplane, intent of operations, size of vehicles (UASs can be much smaller), and speed of flight (UASs can be much slower).

Certification Infrastructure

Certification is about compliance with minimum standards and judgments of equivalent levels of safety. The specific steps of the processes followed for certification depend on what is being certified: design (airplane, engines, and propellers), training programs, pilots, operations specifications, or maintenance programs. All of these certification processes are important in considering introducing UASs into the NAS. Before addressing these certification processes, it is useful to describe the changes in the overall NAS that will occur with the introduction of UASs. Table 2 presents a list of the things that must go through certification for operations in the NAS. Of course, there are many sets of regulations required to accomplish the certification approval for all of these system elements. Table 3 lists these regulations.

Design Certification

The regulations that govern design certification are found in Title 14 of the Code of Federal Regulations (14 CFR) Part 23 (small airplanes), Part 25 (transport (large) airplanes), Part 27 (small rotorcraft), Part 29 (large rotorcraft), Part 31 (balloons), Part 33 (engines), Part 35 (propellers). Notice that full airplanes are certificated, not individual elements of the airplanes. This is a challenge as an approach for UAS design certification because by their nature the flight deck or control station may not be physically attached to the rest of the airplane. Therefore, it is possible to have a control station that is used to control several airplanes at one time or that in many other ways is treated as separate in design and philosophy from the airplane of which it will control.

The definition of an airplane as stated in the regulations is “an engine-driven fixed-wing aircraft heavier than air that is supported in flight by the dynamic reaction of the air against its wings” (14 FAA Order 8110.4C describes the type certification process and how to handle aircraft for which certification applications are received but do not fit into one of the predefined classes of aircraft currently explicitly covered in the regulations. In these cases special conditions are used. The Order states “special conditions are issued only if the existing applicable airworthiness standards do not contain adequate or appropriate safety standards for the aircraft, aircraft engine, or propeller because of novel or unusual design features of the product to be type certificated." This is a method that may be used with UASs until the FAA and applicants gain experience with the certification of UASs.

Even though the language of some of the current regulations may not be directly applicable to UAS design certification, the process for certification is well known and still applicable. The human factors aspects of this process focus on the intended function of the component of the airplane being certified with which the pilot or other users will interact. To do this, assumptions must be made about the user population including language, skills, and experience, environmental factors of the intended operation, and operational factors such as type and range of operation as well as how different parts of the operational system will interact. Many of these assumptions could be very different for UASs than for current operations of manned aircraft. For example, it is possible for small UASs to takeoff and land from many places that do not require the space or configuration of an airport; assumptions must be made about what will be allowed as part of the operational system in the future. In FAA UAS Policy 05-01 it is stated that UASs "range in size from wingspans of six inches to 246 feet; and can weigh from approximately four ounces to over 25,600 pounds." This is a wide range of design that spans many of the current regulation parts from small to large fixed wing airplanes and small to large rotorcraft. In addition there is a similar range in minimum and maximum speeds of these vehicles. This is a much broader range of variability than is currently addressed in the certification process and will certainly have significant implications for decisions that must be made to ensure the current level of safety in the NAS.

Other Certification

The other areas that must be reviewed and approved through certification process will also be significantly affected by the change in nature of UAS design and operational capabilities. Questions are currently being addressed about the minimum requirements to certify pilots who will operate UASs and how those requirements will compare to those currently in place for manned aircraft. Many postulate that there are a set of core skills that are the same for the two situations, but there may be some additional skills required of pilots who are not co-located with the aircraft that they are controlling.

Pilots of manned aircraft are trained and certified to operate specific types of aircraft. Both trained skill and inherent pilot physical and mental characteristics are considered in the evaluation process. Pilots must successfully complete both written and practical tests before being approved to operate each class or type of aircraft. They must also complete recurrent training to maintain their certification. A similar certification process should be determined for UAS pilots. In addition to being certified for a certain type of UAS, a pilot may need to be certified for only certain operations, such as take-off or landing. Other operations may be performed by alternate pilots, unlike a manned flight where the same individual is responsible for all pilot operations.

Strict guidelines regulate the amount of time spent flying a manned aircraft. The same issues that were used to develop these regulations should be evaluated when developing regulations for UASs. UASs may be in the air for extended periods of time, so shift work may be potentially utilized. The unique concerns that pertain to shift work will need to be considered for UAS pilots, to ensure that physical and mental fatigue does not become a factor.

Table 1. Users to be considered in introducing UASs in the NAS

Regulatory organizations o Policy makers o Certifiers	Manufacturing organizations o Designers o Evaluators o Producers	Public
Operating organizations o Dispatchers o Pilots o Other pilots or operators o Ground/ramp crew	Air traffic organizations o Enroute controllers o Terminal area controllers o Ground controllers	Maintaining organizations o Maintainers
Operations training organizations o Pilot/operator trainers	Air traffic training organizations o Air traffic trainers	Maintenance training organizations o Maintenance trainers

Table 2. System elements that must be certified

Airplanes (design and airworthiness) including flight deck (control station for UAS)
Engines and propellers
Modifications to airplanes including flight deck
Operations specifications, programs, and procedures
Pilots
Pilot training programs
Maintenance programs and procedures
Maintenance technicians
Maintenance technician training programs

Similar challenges arise for determining the requirements for approved operations and maintenance. All of these areas of performing in the NAS must be systematically evaluated as decisions are made to broaden the NAS to include UAS operations.

Assumptions that we have always held about the operation of airplanes now come into question for modification and implications. Some of these long held assumptions are that the pilot will always be there to take over if something goes wrong, the automation can always be turned off, the pilot can react to environmental changes in real time, and the pilots are involved in a mission for its full duration. There are many others.

Table 3. Regulation Parts from Title 14 Code of Federal Regulations

Aircraft (design) regulations	**Operator regulations**	**Operations regulations**	**Training organization regulations**
21 General aircraft certification	61 Certification: pilots, flight instructors, and ground instructors	36 Noise standards	141 Pilot schools
23 Small airplanes	63 Certification: flight crewmembers other than pilots	39 Airworthiness directives	142 Training centers
25 Transport airplanes	65 Certification: airmen other than flight crewmembers	43 Maintenance	145 Repair stations
27 Small rotorcraft	67 Medical standards and certification	119 Certification: air carriers and commercial operators	147 Aviation maintenance technician schools
29 Transport rotorcraft	91 General operating and flight rules	121 Operating requirements: domestic, flag, and supplemental operations	
31 Balloons	93 Special air traffic rules	135 Operating requirements: commuter and on demand operations and rules governing persons on board such aircraft	
33 Engines	103 Ultralight vehicles	137 Agricultural aircraft operations	
35 Propellers			

Summary

There is a lot to be done to safely integrate UASs into the NAS and much of it is underway. There are some things we already know how to do well such as certification, design, and evaluation processes. The tasks that will need to be accomplished to operate UASs in the NAS may be different in many aspects, but the principles for defining and evaluating those tasks are the same as are used in our current processes. The technology and design strategies may be different as we design and introduce UASs, but the principles behind these activities are the same. Human factors considerations have been taken into account throughout the certification process for manned aircraft and flight decks. These considerations apply to all segments of manned aircraft, and will also apply to all segments of UAS'. They must be evaluated for UAS control station displays, controls, systems, equipment and procedures. The capabilities of the operator should also be considered, especially if those capabilities are not equivalent to the capabilities of manned aircraft pilots. These considerations will be beneficial in the development of regulations for UAS control stations because they are comprised of the same operator/user focused fundamental principles and processes that exist for manned aircraft. Many assumptions that we have made about the interaction between pilots and aircraft need to be reconsidered and their implications for safety evaluated. This may be the most significant human factors challenge for UAS integration.

There is a lot we as an industry know that we can bring to the table for the challenges of safely integrating UASs into the NAS, and there is still a lot we do not yet know, but we have identified the processes and approaches to develop the knowledge we need.

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