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COVER SHEET
Access 5 Project Deliverable

Deliverable Number: PD014

Title: Initial Experimental Airworthiness Certification Guidance for UAS

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Abstract:
This paper addresses the regulatory processes and requirements already in place by which an applicant might obtain experimental airworthiness certification for a civil UAS. It is more extensive and subsequent to an earlier, similar deliverable, PD007, which was an interim study of the same topic. Since few regulatory airworthiness and operating standards exist for UAS like those for traditional manned aircraft and since most UAS have historically been developed and operated under military auspices, civil use of UAS in the NAS is a new and unfamiliar challenge requiring specific and unique considerations. Experimental certification is the most basic level of FAA approval toward routine UAS operation in the NAS.

The paper reviews and explains existing FAA requirements for an applicant seeking experimental airworthiness approval and details the process for submission of necessary information. It summarizes the limited purposes for which experimental aircraft may be used and addresses pertinent aspects of UAS design, construction and operation in the NAS in harmony with traditional manned aircraft. Policy IPT position is that UAS, while different from manned aircraft, can use the same initial processes to gain civil operating experience under the experimental approval. Particular note is taken of those UAS-unique characteristics which require extra attention to assure equivalent safety of operation, such as the UAS control station and sense-and-avoid. The paper also provides "best practices" guidance for UAS manufacturers and FAA personnel in two appendices. The material in Appendix A is intended to provide guidance on assuring UAS safety to FAA, and provides FAA personnel with a suggested list of items to review, with a focus on UAS unique factors, prior to issuance of an experimental airworthiness certificate. Appendix B provides an outline for a program letter which a manufacturer could use in preparing the application for an UAS experimental airworthiness certificate.

Status:

Access 5-Approved

Limitations on use:
None.

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Subject: UAS Experimental Certification Process and Guidance

Statement of Question/Issue:

The FAA currently has no published criteria for the issuance of an airworthiness certificate for an Unmanned Aircraft System (UAS) that includes the unmanned aircraft, the control station, and command, control, and communication links. Existing requirements are based on manned aircraft. UAS could be considered controversial and unique, thereby requiring the development of acceptable means of compliance with existing and newly developed regulations that will set a national precedent. The experimental certificate would represent an initial and lowest level of certitude to achieve the goal of safely integrating UAS into the National Airspace System (NAS) along with piloted aircraft.

Discussion:

The routine flights of civil UAS in the NAS should require fundamental assurance that these aircraft will not cause unsafe conditions to exist with other manned aircraft and people/property on the ground. Aviation safety begins with a safe aircraft. The FAA promotes the safety of civil aircraft and must have reasonable confidence in their ability to respond to safety issues/concerns, and be able to define and establish an acceptable operating civil environment for a UAS system.

Currently, UAS are limited, with very few exceptions, to operations within restricted airspace. To gain maximum use of UAS, commercial operations will eventually be sought after by manufacturers and operators. UAS are aircraft and as such, under the current regulations will require an applicant to obtain type and airworthiness certificates. The use of experimental airworthiness certificates for specific purposes, are a normal aspect of the certification process. A review of the purposes outlined in the Federal Aviation Regulations (FAR or 14 CFR) and FAA guidance indicates that research and development, showing compliance with 14 CFR, crew training, exhibition, and market survey may be applicable to UAS operations. The following defines each of these specific purposes:

- Research and Development – R&D aircraft are defined as aircraft that test new design concepts, aircraft equipment, installations, operating techniques, or new uses of aircraft.

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Any aircraft would be eligible for an experimental certificate under this purpose. Former military aircraft are often used in R&D projects.

- Showing compliance with Regulations – show compliance aircraft are defined as aircraft that conduct flight tests and other operations to show compliance with the regulations. The purpose is to show compliance with 14 CFR after the applicant has completed R&D, if applicable, by means of flight testing authorized by the FAA.
- Crew training – crew training aircraft are defined as aircraft involved in the training of the applicant's flight crews. These are the manufacturers flight crews needed to operate the aircraft during a certification program or for production flight testing.
- Market Survey – Market survey aircraft are defined as aircraft that are used for conducting market surveys, sales demonstrations, and customer crew training as provided for in 14 CFR 21.195. The FAA representative must ensure that the provisions of 21.195 are met before issuing the certificate. The applicant must provide the FAA representative with the estimated time or number of flights required for the market survey operation as well as the area or itinerary over which the operations are to be conducted under 21.193 (d)(2) and (3).
- Exhibition – Exhibiting the aircraft's flight capabilities, performance, or unusual characteristics at air shows, motion picture, television, and similar productions, and the maintenance of exhibition flight proficiency, including (for persons exhibiting aircraft) flying to and from such air shows and productions.

A review of current Federal Aviation Regulations indicates that rules and policy are in place to permit the use and process the applications for experimental airworthiness certificates for UAS. 14 CFR Part 21.191 through 21.195 provide the regulatory basis for issuing experimental certificates for any aircraft for the purposes indicated. 14 CFR Part 91.319 outlines operating limitations for aircraft with experimental airworthiness certificates that reduce the risk to persons in the air and on the ground. Other 14 CFR parts such as Part 45 and 91.205 support these paragraphs with additional requirements. For UAS experimental airworthiness applications, an equivalent level of safety to piloted aircraft within the experimental aircraft category will be required along with the guidance for FAA personnel and UAS manufacturers on the unique and/or specific areas to be reviewed prior to the issuance of an experimental airworthiness certificate.

It is important to note that the UAS applicant recognizes experimental certification is one step on the path toward type certification and is intended as a tool to benefit the applicant and the FAA in working toward that goal. It does not permit unrestricted operation or operation for hire or compensation, a privilege normally requiring type certification. Other special airworthiness options are available in specific circumstances if the applicant does not wish to pursue type certification. Certificates of Authorization (COA) are typically used for military and 'public aircraft' operations in the NAS. The certification of a UAS by a manufacturer, and the use of the experimental certificate for the appropriate purposes, should not prevent the manufacturer from also using the COA process where applicable.

Of all the approved purposes under an experimental certificate, research and development (R&D) is likely to be the most common initial activity. Market survey and exhibition may also be early applications of experimental airworthiness certificates for UAS manufacturers. The

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following are examples of developmental applications where operating an UAS with an experimental airworthiness certificate for the purpose of research and development is appropriate.

- Development and testing of normal and abnormal/emergency operating procedures.
- Development and testing of sense and avoid systems
- Development and testing of command and control systems
- Development and testing of communication systems
- Development of weather avoidance and protection equipment such as anti-ice.
- Improvements to engines, systems, and components consistent with the demands of long-endurance, high altitude missions.
- Service testing to identify component replacement and maintenance processes.
- Operations of UAS over long periods of time and/or distance.
- Autonomous operations
- Operational hand off between control stations when UAS is transitioning over long distances.
- Testing of communications links between the control station, air traffic control, and the flying aircraft.
- Testing of UAS contingency management subsystems.
- Development and testing of sensors, cameras, communications relays, etc.
- Exploring new applications of UAS (i.e. communications platforms, agricultural monitoring, etc.)

Process:

The following process is proposed to apply for and obtain an experimental airworthiness certificates for the purpose of research and development, showing compliance with regulations, crew training and market survey. Regulations will not need to be changed to meet this process. Some guidance will need to be adjusted though along with a perspective that allows for the system as a whole (i.e. control station, data link, etc.) as the definition of aircraft. Appendix A provides guidance as a 'best practice' that manufacturers can utilize in complying with the requirements for an experimental airworthiness certificate. The process steps are:

1. The applicant must apply for registration per the appropriate sections of 14 CFR Part 47. Access 5 document PD018, Experimental UAS Registration, addresses the registration process.

2. The UAS will be marked in accordance with 14 CFR Part 45.

3. The applicant will develop a program letter outlining the program objectives and aircraft configuration and describing the proposed activity or activities. If the applicant will be utilizing the UAS for different purposes (R&D, market survey, crew training, etc.) then multiple experimental airworthiness certificates will be needed. An outline of a sample program letter is in Appendix B. The program letter should be of enough detail to

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permit the MIDO personnel to prescribe adequate operating limitations and conditions to mitigate risk and ensure safe operation. It is suggested that any previous COA issued for the aircraft also be submitted with the application. The following information is required during the experimental certification process:

a. Time and number of flights (14 CFR21.193(d)(2)) - The program letter should include the estimated time or number of flights required to accomplish the program. The FAA will evaluate the request in comparison to the program in order to establish the appropriate time duration for the Special Airworthiness Certificate.
b. Areas of operation - The program letter should provide sufficient detail to describe the area over which the proposed flights are to be conducted. The FAA has the responsibility to establish the flight test area boundaries.
c. The applicant should describe the aircraft's external configuration. The use of three-view sketches, drawings, and three-dimensional photographs are acceptable.
d. The applicant should describe the control station facility associated with the UAS including enough information about the physical configuration, operating characteristics, control and communications links with ATC and the aircraft, and contingency capabilities, to permit the FAA to determine what additional safety measures or operating considerations might be required.
e. The applicant should describe the process by which essential sense-and-avoid functions normally available to manned experimental aircraft will be fulfilled by the UAS and how it will be mitigated for those functions not fulfilled. FAA may specify additional operating considerations to compensate for shortcomings inherent in UAS capabilities.
f. The applicant will submit an application for an experimental certificate. Forward the Airworthiness Certificate Application form, along with the program letter and any additional data to the local MIDO.

4. The FAA will establish a set of operating limitations based on 14 CFR 91.319 (operating limitations for airplanes with experimental airworthiness (EXP) certificates) and the information provided by the applicant. An inspection of the UAS by an Aviation Safety Inspector (ASI) may also be accomplished. Operating limitations will be designed to fit the specific situation encountered. The ASI may impose additional limitations deemed necessary in the interest of safety. The ASI will review each imposed operating limitation with the applicant to ensure that the operating limitations are understood by the applicant. A suggested list of operating limitations that could be imposed on the UAS, as applicable, is included in Appendix A.

5. 14 CFR 91.319(b) requires an unproven aircraft to be assigned to a flight test area. The assigned test area is prescribed in accordance with 14 CFR 91.305. The applicant should propose the test area in accordance with 14 CFR 91.305. The FAA will evaluate the application to determine that the flight test area does not exceed that which is reasonably required to accomplish the program. Actions pertaining to flight test areas must be coordinated with the nearest office of the FAA Air Traffic Service. The FAA

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will also minimize flight over densely populated areas, and congested airways. Takeoff, departure, and landing approach corridors that create hazards to persons and property will be minimized. Since UAS operational development may require longer flight durations, the test area may be designated along specific routes of sufficient length which will meet both operational and safety requirements.

6. Based on the type of experimental activity for the UAS, it may be possible after the initial flight test operations to obtain a new experimental certificate to expand/modify the flight operations area. Also, if the UAS has previous operating experience, it may be possible to obtain a larger initial flight test area. The applicant must definitively show that the UAS has operated safely throughout its normal range of speeds and all maneuvers to be executed, and has not displayed any hazardous operating characteristics or design features, in order to obtain a larger operating area.

Access 5 Position:

For UAS implemented in the near term, the applicant believes that regulations and certification material do exist for manned aircraft that can fundamentally apply to and address most of the current issues of UAS.

- UAS are aircraft and will be issued an experimental airworthiness certificate for the purposes indicated in accordance with the current regulations and policy.
- The initial experimental certificate will be for the purpose of research and development, showing compliance with regulations, crew training, and market survey.
- Application for aircraft registration will be made in accordance with Part 47.
- UA will be identified with registration marking.
- The UAS will be described in the experimental airworthiness certificate. At a minimum, the aircraft, control station, and command/control link method(s) will be identified on the certificate. A copy of the airworthiness certificate will be displayed in the control station and carried onboard the aircraft.
- An inspection by an ASI will be performed in accordance with Order 8130.2E. The inspection will include the control station as well as the flying aircraft. In the long term, this function may be delegated to a Designated Airworthiness Representative (DAR). Appendix A can be used by the applicant and FAA as guidance for determining that the aircraft are in a condition for safe operation.
- Operations should be conducted with appropriate enabling technology and other aircraft safety enhancing equipment such as anti-collision lights, navigational instruments and equipment, collision avoidance equipment, as well as functional sense and avoid (SAA) and over the horizon (OTH) subsystems and equipment where necessary, etc., and
- Compliance should be demonstrated with specified FAA operating rules and regulations, flight manual imposed limitations, and any other prescribed aircraft and systems operating limitations and conditions, to ensure that airworthiness criteria exist that provide an equivalent level of safety.

For operations of a UAS, there may be additional unique factors that must be addressed from an operational environment to ensure a reasonable and measurable level of safety, such as:

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- Unmanned Aircraft Control Station requirements,

- Reliability and/or failsafe criteria to control the UAS when it uses data link connectivity to provide command and control functions for either normal operations or safety of flight (emergency) conditions.

Guidance for UAS manufacturers and FAA personnel are contained in Appendix A, addressing common and unique UAS factors. The material in Appendix A is intended to provide guidance on demonstrating the safety of the UAS to FAA personnel, and provide FAA personnel with a suggested list of items to review, with a focus on UAS unique factors, prior to issuance of an experimental airworthiness certificate. Appendix B provides an outline of a program letter which a manufacturer could follow in preparing the application for an UAS experimental airworthiness certificate.

Project Coordination:

SEIT	Stratcom	ID	PM				

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Best Practice
Unmanned Aircraft Systems
Experimental Certificates of Airworthiness

SCOPE OF THIS PRACTICE

This practice provides guidance that Unmanned Aircraft System (UAS) manufacturers can utilize in complying with the requirements for the issuance of an experimental airworthiness certificate. The practice may also be utilized by the FAA personnel to inspect and issue UAS airworthiness certificates for R&D, market survey, crew training, and to show compliance with 14 CFR.

BACKGROUND

The experimental certificate represents an initial and lowest level of certitude to achieve the goal of safely integrating UAS into the National Airspace System (NAS) along with piloted aircraft. FAA Order 8130.2 provides guidance to the FAA Aviation Safety Inspectors (ASI) and Designees, in the issuance of airworthiness certificates. The UAS design (i.e. control stations, command & control link, etc.) presents unique inspection requirements not seen on manned aircraft nor addressed in Order 8130.2. This practice provides guidance that the manufacturer and FAA can use to assist them in successfully obtaining an experimental airworthiness certificate for R&D, market survey, exhibition, showing compliance with regulations, and crew training. The information in the practice consists of information provided in other FAA guidance (including type certificated products) and industry best practices.

The experimental certification guidance is separated into the following sections:

- General
- Unmanned Aircraft System Airworthiness
- Control Concept/Strategy
- Unmanned Aircraft System Operations
    - Limitations
    - Maintenance
    - Crew certification
- Hazard Assessment

Other useful references for the manufacturer include the Aeronautical Information Manual, FAA Advisory Circulars and regulations, all available on the FAA website.

APPLICATION REQUIREMENTS

General

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The overriding principle in the issuance of an experimental certificate is that the UAS design and operation should not present or create a hazard to other aircraft in flight or persons and/or property on the ground. Section 91.319(b) requires that an unproven aircraft be assigned to a flight test area. The assigned test area is prescribed in accordance with § 91.305. Under §§ 91.319(b) and 91.305, all initial flight operations of experimental aircraft must be limited to the assigned flight test area until the aircraft is shown to be controllable throughout its normal range of speeds and all maneuvers to be executed, and has not displayed any hazardous operating characteristics or design features. The following sections describe capabilities and information necessary to demonstrate that the UAS will not be a hazard, and can safely operate in the NAS for the purposes indicated in the experimental certificate application.

The UAS differs from manned aircraft in that the pilot is physically separated from the aircraft. Therefore, unmanned aircraft must take into consideration the entire system, versus just the aircraft. The UAS at a minimum will consist of the unmanned aircraft, a control station, and command, control, and communication links. All of these elements of the UAS contribute to an airworthy system.

UAS Experimental Airworthiness Certificates should only be issued to the UAS manufacturers, for operations according to the certificate purpose.

The UAS shall be registered in accordance with 14 CFR Part 47, Aircraft Registration and marked in accordance with 14 CFR Part 45; Identification & Registration Marking;. The aircraft shall display nationality and registration marks in accordance with 14 CFR 45.21 and the word "EXPERIMENTAL" displayed in accordance with 14 CFR 45.23.

UAS certified as experimental do not meet the requirements of the applicable, comprehensive, and detailed airworthiness code as provided by Annex 8 of the ICAO. The manufacturer of the UAS must obtain written permission from another country's CAA prior to operating the aircraft in or over that country. That written permission must be carried aboard the aircraft and posted at the control station and/or manufacturer's place of business together with the U.S. Airworthiness Certificate and, upon request, be made available to an FAA inspector or the CAA in the country of operation.

Unmanned Aircraft System Airworthiness

The Unmanned Aircraft (UA) is the flying part of the UAS. It consists of the structure and all of the subsystems required for operation. The UA must be constructed and maintained in an airworthy condition. For the purposes of this discussion, "airworthy" means the UA must be in condition for safe operation. The aircraft structure, primary flight controls system, other systems and equipment (i.e., electrical, hydraulics, avionics, software, etc.) including the propulsion and power-plant installation, should incorporate features which will provide for the safe functioning or recovery of the aircraft in the event of a system(s) malfunction or failure.

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A system description should be presented along with the program letter. This description along with supporting data will assist the FAA in understanding the UAS and any new and novel features over and above a manned aircraft. The UAS description should include information in the following areas to show the design and construction of an airworthy aircraft. The information/data could come from design documentation and/or prior ground and flight operations.

- Describe the capability of the airframe structure to withstand expected flight loads and provide data/analysis to show that it is flutter-free throughout the flight envelope.
- Describe the aircraft fuel system and how it allows for adequate control of the fuel delivery to the engine, and provides for aircrew determination of fuel remaining.
- Describe the propulsion system and its ability to provide reliable and sufficient power to takeoff, climb, and maintain flight at expected mission altitudes.
- Describe the auxiliary power systems (electrical, hydraulic, pneumatic, etc.) and explain how it was determined that they have sufficient reliability and provide sufficient power to safely operate the aircraft.
- Describe the thermal management system (e.g. cooling air), and how it provides sufficient capability to enable continued operation of flight critical functions. If no thermal management system is installed, explain why it is not necessary.
- The UA should have anti-collision and position lights installed in accordance with FAA criteria. These lights should be turned on at all times while the aircraft is in flight, unless directed otherwise by the controlling civil aviation authority.
- Describe how the landing system(s) allow for safe recovery of the aircraft without damage to the aircraft or landing area.
- Describe the performance of the aircraft within the flight envelope. The flight envelope should be described using a V-N (velocity loading) diagram and the following speeds. These speeds define the basic parameters of the flight envelope and key operating points to achieve maximum performance from the aircraft and avoid overloading the aircraft structure.
    - Power off stall speed (Vso)
    - Maneuvering speed (Vma)
    - Never exceed speed (Vne)
    - Best rate-of-climb airspeed (Vy)
    - Approach airspeed(s) (Vapp) in normal approach/landing configurations
    - Mach limits, if applicable
    - Minimum control speed with the critical engine inoperative (Vmc), if a multi-engine aircraft with engines mounted off the centerline.
    - Any other speed(s) unique to the UA operation.
- Describe the operation of the flight recovery system, or explain why a flight recovery system is not required.
- Describe the stability and control of the aircraft throughout the flight envelope.
- Describe the weight and balance envelope for the aircraft, and provide an actual empty weight and center-of-gravity from scale measurements. Describe the gross weight of the aircraft, and the analysis of how it was determined.

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The UAS should be equipped with instruments which will enable the flight crew to control the flight path of the airplane, carry out any required procedural maneuvers, and observe the operating limitations of the airplane in the expected operating conditions.

UAS Equipage

The UAS, at the minimum, should be provided with the instruments and instrumentation required for IFR operations. Additional sensors and/or analysis tools should be available to detect developing problems that are not obvious from the normal instrumentation.

An operable Mode S Transponder coupled to an altitude encoding altimeter shall be installed in accordance with 14 CFR 91.215. The pilot of the aircraft should have the capability to turn the transponder on and off, select codes, and squawk ident as directed by ATC.

If the aircraft is to be operated between FL 290 and FL 410, it shall have RVSM capable altimetry in accordance with 14 CFR Part 91, Appendix G.

For operations above FL240 the UAS is required to be able to determine DME or GPS distance to published navigation fixes.

If the UAS uses GPS a primary means of IFR navigation, then an alternate means of navigation must be available (i.e. Inertial Navigation System or VOR)

The UAS shall be equipped to conduct VHF communications with ATC in which the UA is operated.

In addition to the minimum equipment necessary for the issuance of a certificate of airworthiness, certain other instruments, and equipment, may be required and should be installed, as appropriate, according to the airplane use and for the special purpose operations under which the flight is to be conducted.

Control Concept/Strategy

Command, control and communication links are an integral part of the UAS. The system description must also clearly document the control concept/strategy design, implementation, and operation. The following elements should be addressed to fully describe the control concept for the UAS.

- Describe the command and control capability of the UAS.
    a. Describe the UA control system(s) that provide control of the UA systems in conjunction with or absent a control input from the control station.
        i. Describe whether this architecture is centralized or distributed, and which portions, if any, are dependent on a data link.
        ii. Describe all flight critical functions for which the Executive is responsible, i.e., whether the executive is required to provide basic aerodynamic stability of the aircraft.

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b. Describe the Control Link connecting the UA and the control station.
    i. Describe the frequencies used, methods used, and LOS/BLOS capability of the control link.
    ii. Address any tradeoffs between the persistence and integrity of the control link, i.e., does a UA with limited autonomy have a control link that has been proven to be available for nearly all of the flight?
c. Describe the Control Station and the Control Layout.
    i. Is there a one-to-one correspondence between each control station and each aircraft, or is control handed off between multiple control stations? Conversely, are multiple aircraft handled by a single control station?
    ii. Does the pilot use conventional, aircraft-type controls (stick/rudder), or do the controls correspond to a "pilot-on-the-loop" concept where the pilot makes computer inputs (mouse/keyboard) to change auto-pilot settings in the aircraft?
    iii. Do the Controls and Displays correspond to the Control Layout (i.e. conventional aircraft for stick/rudder vs. mission overview for mouse/keyboard)? Does the pilot have all required information on the UAS state displayed in a manner that is both intuitive and unambiguous?
    iv. Does the pilot have adequate control of aircraft flight path (attitude, altitude, heading) and speed for normal operations and contingencies with the control concept provided?
    v. Describe the method of providing power to the control station. Is the redundancy of power appropriate to the control concept in (b)(ii)?
    vi. Is the environment of the control station controlled in a manner that is appropriate to the length/type of missions it is used for?
d. Demonstrate that the Navigation System is adequate to locate the aircraft in space and time.
    i. If the aircraft is not on the desired course or at the desired position, can corrections be made in time to prevent excursions outside airway bounds, or deviating from an ATC clearance?
    ii. Is the aircraft equipped for Reduced Vertical Separation Minimum (RVSM) operation?
    iii. Does the aircraft meet Required Navigation Performance (RNP), and will it operate in RNP defined airspace?
e. Describe how the aircraft will meet the requirement of 14 CFR 91.113 to "see and avoid other aircraft" and give "right-of-way."
    i. Do the methods used change for different categories of airspace?
f. Describe the security of the UAS.
    i. How is the command and control of the UA protected from unauthorized takeover, spoofing, jamming, etc?
    ii. How is the pilot protected from interruptions?
g. Describe how different contingencies are handled by the UAS.
    i. What steps are taken to mitigate the effects of the following malfunctions?
        1. Loss of command and control link.
        2. Loss of communications.

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3. Loss of propulsion.
4. Loss of electrical system.
5. Loss of other onboard systems which are essential to flight.

ii. How is flight terminated with a flight critical system failure?

iii. What methods were used to validate the contingency management function (i.e. simulation, analysis, etc.)?

The Control Station (CS) provides the Human-Systems Interface (HSI) for operating the UA. Since the pilot is not physically in the UA, he/she works without the peripheral cues normally available. Therefore the CS should provide enough information to assure a level of situational awareness to the pilot similar to that for a pilot flying a manned airplane. The nominal functions of the CS will be to: monitor the health of flight and mission critical systems; facilitate communications with ATC; and provide positive control of the UA by the pilot. The CS will include displays, enunciators (visual + audio), and computer equipment necessary to ensure safe control of the vehicle's flight path/speed, and an equivalent level of safety with respect to See, and Avoid capabilities of a manned aircraft in the same category/class. Other equipment not essential to safety may be considered acceptable on a no hazard basis.

The CS shall be configured to ensure the pilot is informed of any degraded mode of operations due to failure, including cases in which there is an automatic switching to an alternate or degraded mode of operation. The control station shall include a diagnostic and monitoring capability for the status of the aircraft. Real time, direct communications and surveillance, and data transmission capability may be provided in the absence of failure. For operations in the controlled airspace, direct communications with ATC should be incorporated into the control station system design.

The CS should provide a safe and secure environment for the PIC of the UA. Since the CS is fixed on the ground, crashworthiness is not an issue. However, the CS should protect the pilot from fire, smoke, or other harmful or potentially incapacitating hazards. The CS should protect the pilot from interruptions, either unintentional or deliberate, while they are performing their crew duties.

The pilot of a manned aircraft, due to being located on the aircraft during flight has the ability and responsibility to keep the aircraft from departing the flight test area. Control of the UAS is dependent upon the software installed on the UAS. Given that aspect of the UAS the manufacturer should consider the process and software levels of the control system software as a part of the aircraft qualification for an experimental certificate. The software development has to be rigorous enough to minimize the possibility of the aircraft departing the flight test area. The applicant should be able to provide to the FAA the methods, processes and testing accomplished for the installed software.

An alternative method of compliance to the software requirements above is to have a termination system onboard that will, under control of the pilot, positively prevent the UAS from departing the flight test area. Examples could include Ballistic Recovery Systems, explosive bolts on wing attach fittings, etc.

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UAS operations should have means of collision avoidance (in lieu of conventional on-board pilot see & avoid capability) that provides an equivalent level of safety to manned aircraft. Depending on the proposed operations, such a means could include one or a combination of the following methods:

- A chase plane.
- Ground observers.
- Ground-based primary or secondary radar.
- On-board cooperative sensors.
- Other sensor systems.

The UAS navigation system should be capable of providing the UAS with the accuracy required for operations conducted under IFR, in accordance with 14 CFR Part 91. The pilot of the vehicle should be provided with the aircraft position, azimuth, altitude, and distance in relation to published navigational aids or fixes and provide a capability to fly along published airways or other standard routes.

The vehicle navigation system should meet the required navigation performance (RNP) standards for the airspace classification in which the operations are to be conducted. Navigation system designs should consider the complexity and level of air traffic operations found in the airspace in which the UAS will be operated.

UAS Operations

As part of the operations of aircraft with an experimental airworthiness certificate, the FAA will usually limit the operation of an UAS to a defined flight test area. The initial flight test area should be restricted to lightly populated areas and not include congested airways or high density airports. The initial flight test area restrictions should remain until sufficient data is obtained to convince the FAA that the unmanned aircraft is airworthy, controllable, and safe to operate in an expanded area.

The UAS should have a means to determine and avoid the likely presence of severe weather. This could be satisfied by real-time access to ground-based weather radar information at the ground station.

Aircraft operating limitations and conditions are prescribed in the aircraft flight manual. The FAA may impose any additional limitations deemed necessary. The limitations could also include operational restrictions such as performance, weight, altitude, speeds, etc. These restrictions can be implemented through the operating limitations attached to the airworthiness certificate, as well as operating limitations in the regulations themselves.

Limitations:

The following operating limitations are normally prescribed as applicable. Other limitations also may be deemed applicable.

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- No person may operate this aircraft for other than the purpose approved by the certificate to accomplish the flight operation outlined in the program letter found in Appendix C, describing compliance with 14 CFR 21.193(d) and made available to the pilot-in-command of the aircraft. Additionally, this aircraft shall be operated in accordance with applicable air traffic and general operating rules of 14 CFR Part 91, and all additional limitations herein prescribed under the provisions of 14 CFR 91.319(e).
- All flights shall be conducted within the geographical area described by radius, or coordinates, and/or landmarks. The designated area normally must be over open water or sparsely populated areas having light air traffic, and should allow transition access to the airspace above FL410. The size of the area shall be that required to safely conduct the type of anticipated maneuvers and tests, as appropriate. Multiple purpose certificates may require individually prescribed geographical areas. This applies to all certificates issued to show compliance with 14 CFR 91.319(b). The aircraft will not be allowed to operate over densely populated areas or in congested airways in accordance with 14 CFR 91.319(c). When the FAA finds compliance, the operating limitations will be revised accordingly.
- When changing between operating purposes of a multiple purpose certificate, the operator shall determine that the aircraft system is in a condition for safe operation and appropriate for the purpose intended. A record entry will be made by an appropriately rated person to document that finding in the aircraft log book.
- This aircraft may be operated under IFR, and must be properly equipped for instrument flight in accordance with 14 CFR 91.205. 14 CFR 91.319(d)(2) provides for VFR, day only, unless otherwise specifically authorized by the Administrator. This limitation gives that authorization. If other operations are requested, the aircraft must be equipped in accordance with the applicable requirements of 14 CFR 91.205.
- No person may operate this aircraft for carrying persons or property for compensation or hire.
- This UAS shall contain the placards, markings, etc., as appropriate to UAS.
- This aircraft may conduct aerobatic flight in accordance with the provisions of 14 CFR 91.303. Aerobatics shall not be attempted until sufficient flight experience has been gained to establish that the aircraft is satisfactorily controllable and in compliance with 14 CFR 91.319(b). Aerobatic maneuvers intended to be performed must be satisfactorily accomplished and recorded in the aircraft records during the flight test period.
- The pilot-in-command of this aircraft shall notify ATC of the experimental nature of this aircraft when operating into or out of airports with operating control towers. The pilot-in-command shall plan routing that will avoid densely populated areas and congested airways in compliance with the designated test areas.
- Aircraft instruments and equipment installed and used under 14 CFR 91.205 must be inspected and maintained in accordance with the requirements of 14 CFR Parts 43 and 91. Any maintenance or inspection of this equipment must be recorded in the aircraft maintenance records
- Application must be made to the geographically responsible FSDO or MIDO for any revision to these operating limitations.

Prior to issuing operating limitations for the unmanned aircraft system (UAS), the certificating inspector will coordinate approach and departure corridors with the FSDO Operations Unit and

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the ATC Facility that has the geographical responsibility for the airport on which the UAS will be based or operations conducted. In addition, the manufacturer should provide a highlighted aeronautical map or chart depicting the proposed operational area, including a list of the proposed alternate airports. The map or chart is considered part of the aircraft operating limitations. Operation of all aircraft will be restricted to designated airports that are outside Class B airspace (see Aeronautical Information Manual and 14 CFR 91.126 through 91.130).

A new experimental certificate (FAA Form 8130-7) is required whenever operating limitations are amended, because the date of the old limitations shown on the corresponding certificate would not be in accordance with the date of the new limitations, and alteration of the certificate to change the date is not permitted. The FAA inspector and/or designee will normally review each operating limitation imposed with the applicant, to ensure that they are understood by the applicant.

Maintenance

The manufacturer should develop and document an inspection and maintenance program that includes the following topics.

- Inspection
- Servicing
- Corrosion Control
- Configuration Control (Logbooks)
- Crew rating requirements

Each UAS that is operated needs to be maintained in an airworthy condition so as to ensure that the aircraft's certificate of airworthiness remains valid. UA maintenance is intended to address inspection, overhaul, repair, preservation, and replacement of components or parts of an UAS. The use of normal small aircraft maintenance procedures should be sufficient for UA. The UA should be inspected at least annually to ensure it remains in an airworthy condition. Heavyweight or very lightweight UA may require a different inspection interval for structural surveillance.

Maintenance of the UAS by the operator should follow the fundamental guidance contained in FAA Advisory Circulars (AC) No. 43.13-2A, Acceptable Methods, Techniques, and Practices Aircraft Alterations, and No. 43.13-IB, Acceptable Methods, Techniques, and Practices Aircraft Inspection and Repair, unless otherwise notified. The manufacturer’s recommendations are not required unless implemented as part of an Airworthiness Directive.

Modifications and repairs should likewise comply with the applicable airworthiness requirements. Procedures should be established to ensure that the substantiating data supports compliance with applicable airworthiness requirements.

No person shall operate this UAS unless within the prescribed 12 calendar months it has had a condition inspection performed in accordance with the scope and detail of Appendix D to 14 CFR Part 43, or other FAA approved programs, and found to be in a condition for safe operation. This inspection will be recorded in the aircraft maintenance records. Only FAA certificated

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mechanics with appropriate ratings as authorized by 14 CFR 43.3, or the manufacturer, may perform required inspections.

Inspections shall be recorded in the aircraft maintenance records showing the following or similarly worded statement: *"I certify that this aircraft has been inspected on (insert date) in accordance with the scope and detail of Appendix D to 14 CFR Part 43, or other FAA approved programs and found to be in a condition for safe operation."* The entry will include the aircraft total time in service, and the name, signature, certificate number, and type of certificate held by the person performing the inspection.
Records shall be kept of the following: (1) the total time in service (hours, calendar time, and cycles as appropriate) of the airplane including all life limited components, (2) current status of compliance with all mandatory continuing airworthiness information, (3) appropriate details of modifications and repairs to the airplane and its major components, (4) time in service (hours, calendar time, and cycles as appropriate) since last overhaul of the airplane or its components subject to a mandatory overhaul life, (5) current airplane status of compliance with the maintenance program, and (6) detailed maintenance records to show that all requirements for signing off a maintenance release have been accomplished.

In addition, a record should be kept for the CS, which documents maintenance and modifications to the CS, and provides a current, accurate description of the CS configuration, to include the software configuration.

Aircraft instruments and equipment installed and used under 14 CFR 91.205 must be inspected and maintained in accordance with the requirements of 14 CFR Parts 43 and 91. Any maintenance or inspection of this equipment must be recorded in the aircraft maintenance records.

If any of the following occur during operation, it should be documented and made available to the NTSB/FAA if requested:

- Fires caused by a system or equipment failure, malfunction, or defect.
- An engine exhaust system failure, malfunction, or defect, which causes damage to the engine, adjacent aircraft structure, equipment, or components.
- The accumulation or circulation of toxic or noxious gases in the crew compartment (Unmanned Aircraft Control Station).
- A malfunction, failure, or defect of a propeller control system.
- A propeller or blade structural failure.
- Flammable fluid leakage in areas where an ignition source normally exists.
- A brake system failure caused by structural or material failure during operation.
- A significant aircraft primary structural defect or failure caused by any autogenous condition (fatigue, under-strength, corrosion, etc).
- Any abnormal vibration or buffeting caused by a structural or system malfunction, defect, or failure.

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- An engine failure.
- Any structural or flight control system malfunction, defect, or failure, which causes an interference with normal control of the aircraft or which derogates the flying qualities.
- A complete loss of more than one electrical power generating system or hydraulic power system during a given operation of the aircraft.
- A failure or malfunction of more than one attitude, airspeed, or altitude instrument during a given operation of the aircraft.
- Any other failure, malfunction, or defect affecting the safe operation of the UAS such as:
    - Command & Control Link
    - Communication Link
    - Navigation System
    - Control Station (CS)
    - Collision Avoidance

The manufacturer should provide an aircraft operating manual, containing the normal, abnormal, and emergency procedures relating to the operation of the UAS. The manual should include details of the aircraft systems and of the checklists to be used. The design of the manual should observe human factor principles.

Checklists should be available and used by personnel prior to, during, and after all phases of UAS operations, and in emergencies, to ensure compliance with the operating procedures contained in the flight manual or other limitations associated with the certificate of airworthiness. The design and utilization of checklists should observe human factors principles.

The following general operating procedures for UAS operations are recommended as a supplement to 14 CFR Part 91:

- The UAS Pilot in Command (PIC) will be designated by name on a flight log kept in the CS. Each PIC will sign in/out on log for multi-PIC flights.

- In the event of failure of communications between the UAS PIC and ATC, the UAS transponder should be set to code 7600 and normal 14 CFR 91.185, IFR Operations: Two-way Radio Communications Failure procedures should be followed.

- Prohibited UAS flight operations should include: special VFR operations, and operations in known icing conditions.

- In the event of loss of the command & control link, the PIC will notify ATC and follow prescribed procedures. If the UA poses a hazard to other aircraft or persons/property on the ground, UA recovery will be initiated. If the UA does not pose a hazard, then the flight may continue while attempts are made to reestablish the command & control link.

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Crew Certification

The pilot-in-command of the UAS must hold an airman certificate with an appropriate rating, plus UAS supplemental training provided by the manufacturer. If the UAS is to be operated IFR, the pilot-in-command, must have at a minimum a Private pilot certificate with an Instrument rating. If required for the type of aircraft to be flown, the pilot-in-command also must hold either an appropriate type rating or a letter of authorization issued by an FAA Flight Standards Operations Inspector. A letter of authorization is issued in accordance with the procedures described in FAA Order 8700.1, Volume 2, Chapter 32, Section 1 for all training and eligibility requirements. This limitation is applicable to any turbine-powered aircraft.

Proper Authorization

In addition to having an airworthy aircraft and safe control and operating procedures/limitations, the proper documentation must be in place to show compliance with the legal requirements. The following documents must be available for inspection when requested.

- Experimental Airworthiness Certificate. The airworthiness certificate must be carried in the UA with a copy available in the control station. The experimental airworthiness certificate will describe the allowable operating area and appropriate limitations.
- Registration. The registration must also be carried in the UA with a copy available in the control station.
- Flight Plan. An FAA flight plan must be filed prior to each flight. Any other agreements/authorizations must also be completed/approved as required.
- Logbooks. The logbooks must document the current configuration of the UAS, including software configuration, and be signed off by an appropriately rated person or the designated manufacturing official. All required inspections must be complied with, documented, and signed off by an appropriately rated/designated person. Any maintenance which affects the configuration or airworthiness of the UAS must be documented.
- Service Manuals. Service manuals or other documentation used for servicing, modifying, or repairing the UAS must be identified and available for use by maintenance personnel.
- Flight Manuals. Flight manuals or other documentation describing the UAS along with normal and emergency operating procedures must be available for use by the aircrew. The flight manuals do not need to be approved.

Hazard Assessment

The technical and operational factors, shown earlier, look at the UAS from the perspective of making sure the design and operation of the UAS is safe. The hazard assessment addresses potential hazards and mitigations to those hazards from a perspective of when things go wrong.

The first step in the hazard assessment is to identify potential hazards to the operation of the UAS. A hazard in this case is any condition that has the potential to cause a mishap. Two

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elements of the hazard, cause and effect, must be defined to properly describe the hazard. Hazards will be classified in one of the following categories:

- Catastrophic
- Critical
- Marginal
- Negligible

The choice of category is dependent upon the damage to the UAS, or persons/property on the ground.

Following identification and classification of hazards, the next step is to minimize the probability of occurrence of the hazard. This can be accomplished either through design or procedural methods. Catastrophic hazards must be minimized through design. Procedural steps alone are not sufficient to mitigate catastrophic causes.

Any hazards rated above "Negligible" must also have a corrective action plan developed and documented to describe the steps to be taken to mitigate the hazards' effects.

The results of the hazard assessment must be provided to the MIDO or other designated FAA office prior to the issuance of an experimental airworthiness certificate. At a minimum, the following hazards must be addressed.

- Midair collision with another aircraft
- UA flight outside of the assigned flight test area (i.e. runaway UA)
- Engine failure

APPROVAL PROCESS

1. The applicant must apply for registration per the appropriate sections of 14 CFR Part 47.

2. The UAS will be marked in accordance with 14 CFR Part 45.

3. The applicant will develop a program letter outlining the program objectives and aircraft configuration and describing the proposed activity or activities. If the applicant will be utilizing the UAS for different purposes (R&D, market survey, crew training, etc.) then multiple experimental airworthiness certificates will be needed. An outline of a sample program letter is in Appendix C. The program letter should be of enough detail to permit the MIDO personnel to prescribe adequate operating limitations and conditions to mitigate risk and ensure safe operation. It is suggested that any previous COA issued for the aircraft also be submitted with the application. The following information is required during the experimental certification process:
    a. Time and number of flights (14 CFR21.193(d)(2)) - The program letter should include the estimated time or number of flights required to accomplish the program. The FAA will evaluate the request in comparison to the program in order to establish the appropriate time duration for the Special Airworthiness Certificate.

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b. Areas of operation - The program letter should provide sufficient detail to describe the area over which the proposed flights are to be conducted. The FAA has the responsibility to establish the flight test area boundaries.
c. The applicant should describe the aircraft's external configuration. The use of three-view sketches, drawings, and three-dimensional photographs are acceptable.
d. The applicant should describe the control station facility associated with the UAS including enough information about the physical configuration, operating characteristics, control and communications links with ATC and the aircraft, and contingency capabilities, to permit the FAA to determine what additional safety measures or operating considerations might be required.
e. The applicant should describe the process by which essential sense-and-avoid functions normally available to manned experimental aircraft will be fulfilled by the UAS and how it will be mitigated for those functions not fulfilled. FAA may specify additional operating considerations to compensate for shortcomings inherent in UAS capabilities.
f. The applicant will submit an application for an experimental certificate. Forward the Airworthiness Certificate Application form, along with the program letter and any additional data to the local MIDO.

4. The FAA will establish a set of operating limitations based on 14 CFR 91.319 (operating limitations for airplanes with experimental airworthiness certificates) and the information provided by the applicant. An inspection of the UAS by an Aviation Safety Inspector (ASI) may also be accomplished. Operating limitations will be designed to fit the specific situation encountered. The ASI may impose additional limitations deemed necessary in the interest of safety. The ASI will review each imposed operating limitation with the applicant to ensure that the operating limitations are understood by the applicant. Application must be made to the geographically responsible FSDO or MIDO for any revision to these operating limitations.

   The following operating limitations are suggested as an initial set. Other limitations may be deemed applicable, and/or some of these may not apply in all situations.

   - No person may operate this aircraft for other than the purpose approved by the certificate to accomplish the flight operation outlined in the program letter, describing compliance with 14 CFR 21.193(d) and made available to the pilot-in-command of the aircraft. Additionally, this aircraft shall be operated in accordance with applicable air traffic and general operating rules of 14 CFR Part 91, and all additional limitations herein prescribed under the provisions of 14 CFR 91.319(e).
   - All flights shall be conducted within the geographical area described as follows: (the area shall be described by radius, or coordinates, and/or landmarks). The designated area must be over open water or sparsely populated areas having light air traffic, and allow transition access to the airspace above FL180. The size of the area shall be that required to safely conduct the type of anticipated maneuvers and tests, as appropriate. Multiple purpose certificates may require individually prescribed

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geographical areas. This applies to all certificates issued to show compliance with 14 CFR 91.319(b). The aircraft will not be allowed to operate over densely populated areas or in congested airways in accordance with 14 CFR 91.319(c). When the FAA finds compliance, the operating limitations will be revised accordingly.

- When changing between operating purposes of a multiple purpose certificate, the operator shall determine that the aircraft system is in a condition for safe operation and appropriate for the purpose intended. A record entry will be made by an appropriately rated person to document that finding in the aircraft log book.
- This aircraft system shall not be operated unless it is inspected and maintained in accordance with appropriate military technical publications and/or manufacturer's recommendations. The owner/-operator shall select, establish, identify, and use an inspection program as set forth in 14 CFR91.409(e), (f), (g), and (h). This inspection program shall be recorded in the aircraft maintenance records.
- The pilot-in-command of this UAS must hold an airman certificate with appropriate rating as will be determined and approved by the FAA. If required for the type of aircraft to be flown, the pilot-in-command also must hold either an appropriate type rating or a letter of authorization issued by an FAA Flight Standards Operations Inspector. A letter of authorization is issued in accordance with the procedures described in FAA Order 8700.1, Volume 2, Chapter 32, Section 1 for all training and eligibility requirements. This limitation is applicable to any turbine-powered aircraft.
- This aircraft may be operated under IFR, and must be properly equipped for instrument flight in accordance with 14 CFR 91.205. 14 CFR 91.319(d)(2) provides for VFR, day only, unless otherwise specifically authorized by the Administrator. This limitation gives that authorization. If other operations are requested, the aircraft must be equipped in accordance with the applicable requirements of 14 CFR 91.205.
- No person may operate this aircraft for carrying persons or property for compensation or hire.
- This UAS shall contain the placards, markings, etc., as appropriate to UAS.
- This aircraft may conduct aerobatic flight in accordance with the provisions of 14 CFR 91.303. Aerobatics shall not be attempted until sufficient flight experience has been gained to establish that the aircraft is satisfactorily controllable and in compliance with 14 CFR 91.319(b). Aerobatic maneuvers intended to be performed must be satisfactorily accomplished and recorded in the aircraft records during the flight test period.
- No person shall operate this aircraft unless, within the prescribed 12 calendar months, it has had a condition inspection performed in accordance with the scope and detail of Appendix D to 14 CFR Part 43, or other FAA-approved programs, and found to be in a condition for safe operation. This inspection will be recorded in the aircraft maintenance records.
- Only FAA-certificated mechanics with appropriate ratings as authorized by 14 CFR 43.3, or the UAS component manufacturer may perform inspections required by these operating limitations.
- Inspections shall be recorded in the aircraft maintenance records showing the following or similarly worded statement: *"I certify that this aircraft has been inspected on (insert date) in accordance with the scope and detail of Appendix D to 14 CFR Part 43, or other FAA approved programs and found to be in a condition*

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for safe operation." The entry will include the aircraft total time in service, and the name, signature, certificate number, and type of certificate held by the person performing the inspection.

- The UA must display the word EXPERIMENTAL in accordance with 14 CFR 45.23(b).
- The pilot-in-command of this aircraft shall notify the ATC of the experimental nature of this aircraft when operating into or out of airports with operating control towers. The pilot-in-command shall plan routing that will avoid densely populated areas and congested airways in compliance with the designated test areas.
- This aircraft does not meet the requirements of the applicable, comprehensive, and detailed airworthiness code as provided by Annex 8 of the ICAO. The owner/operator of this aircraft must obtain written permission from another country's CAA prior to operating this aircraft in or over that country. That written permission must be carried aboard the aircraft and posted at the ground control facility and/or operator's place of business together with the U.S. Airworthiness Certificate and, upon request, be made available to an FAA inspector or the CAA in the country of operation.
- Aircraft instruments and equipment installed and used under 14 CFR 91.205 must be inspected and maintained in accordance with the requirements of 14 CFR Parts 43 and 91. Any maintenance or inspection of this equipment must be recorded in the aircraft maintenance records

5. 14 CFR 91.319(b) requires an unproven aircraft to be assigned to a flight test area. The assigned test area is prescribed in accordance with 14 CFR 91.305. The applicant should propose the test area in accordance with 14 CFR 91.305. The FAA will evaluate the application to determine that the flight test area does not exceed that which is reasonably required to accomplish the program. Actions pertaining to flight test areas must be coordinated with the nearest office of the FAA Air Traffic Service. The FAA will also minimize flight over densely populated areas, and congested airways. Takeoff, departure, and landing approach corridors that create hazards to persons and property will be minimized. Since UAS operational development may require longer flight durations the test area may be designated along specific routes of sufficient length which will meet both operational and safety requirements.

6. Based on the type of experimental activity for the UAS, it may be possible after the initial flight test operations to obtain a new experimental certificate to expand/modify the flight operations area. Also, if the UAS has previous operating experience, it may be possible to obtain a larger initial flight test area. The applicant must definitively show that the UAS has operated safely throughout its normal range of speeds and all maneuvers to be executed, and has not displayed any hazardous operating characteristics or design features, in order to obtain a larger operating area.

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Appendix B: SAMPLE PROGRAM LETTER, APPLICANT PROGRAM LETTER SPECIAL AIRWORTHINESS CERTIFICATE

1. Registered Owner (as shown on Certificate of Aircraft Registration)

NAME ADDRESS

2. Aircraft Description

1. Registration Mark 2. Aircraft Builder 3. Yr. Mfg.

4. Aircraft Serial No. 5. Aircraft Model Designation

3. Describe Program Purpose for which the aircraft is to be used (14 CFR 21.193(d)(1).

4. List estimated flight hours required for program. Hrs.: List

estimated number of flights required for program. No. Flts: List

estimated duration for programs (14 CFR 21.193(d)(2)). No. Days:

5. Describe the areas over which the flights are to be conducted, and address of base operation (14 CFR 21.193(d)(3)).

6. Describe the aircraft/system configuration (attach three-view drawings or three-view dimensioned photographs of the aircraft) (14 CFR 21.193(b)(4)).

7. Date Name and Title (Print or Type) Signature

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