THIRD PARTY RESEARCH. PENDING FAA REVIEW.

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The FAA's Center of Excellence for UAS Research
ASSURE
Alliance for System Safety of UAS through Research Excellence

A10 – Human Factors Considerations of UAS Procedures and Control Stations: Tasks PC-1 through PC-3

Pilot and Crew (PC) subtask

Recommended Requirements and Operational Procedures

August 30,2017

Final Report

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16. Abstract

The Alliance for System Safety of UAS through Research Excellence (ASSURE) conducted research focused on minimum pilot procedures and operational practices used by unmanned aircraft systems (UAS) operators today for the purpose of developing recommendations. This research recommends four pilot and 46 operational minimum procedures to operate a civil single-engine, fixed-wing, single-pilot-configured UAS flying in beyond visual line-of-sight (BVLOS) conditions. These recommendations are anticipated to support potential future aircrew procedure requirements for UAS larger than 55 lbs. operating in the National Airspace System (NAS). These procedures were validated using representative Control Stations in simulated environments.

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ACRONYMS

AC	Advisory Circular
ACS	Airman Certification Standards
ADI	Attitude Director Indicator
ADM	Aeronautical Decision Making
AFM	Airplane Flight Manual
AIAA	American Institute of Aeronautics and Astronautics
ALTS	Automatic take-off/landing system
AO	Aircraft Operator
AVO	Air Vehicle Operator
ASSURE	Alliance for System Safety of UAS through Research Excellence
ASTM	American Society for Testing Materials
ATC	Air Traffic Control
ATS	Air Traffic Service
BVLOS	Beyond Visual Line of Sight
CASA	Australian Civil Aviation Safety Authority
CFR	Code of Federal Regulation
CGCS	Common Ground Control System
CL	Checklist
COTS	Commercial Off-the-Shelf
CRM	Crew Resource Management
CS	Control Station
DOD	Department of Defense
DVI	Direct Voice Input
EASA	European Aviation Safety Agency
EO	Electro-Optical
EVLOS	Extended Visual Line of Sight
FAA	Federal Aviation Administration
FLIP	Flight Information Publication
GCS	Ground Control Station
HMD	Head-Mounted-Display
HUD	Head-Up-Display
ICAO	International Civil Aviation Organization
IOC	Instructor Operator Console
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
ITAR	International Traffic in Arms Regulations
KSA	Knowledge, Skills, and Abilities
LOS	Line of Sight
MASPS	Minimum Aviation System Performance Standards
MCS	Mission Control Station
MOPS	Minimum Operational Performance Standards
MTS	Multi-Spectral Targeting System
MUSE	Multiple Unified Simulation Environment
NAS	National Airspace System

NASA	National Aeronautics and Space Administration
PIC	Pilot-in-Command
POH	Pilots Operating Handbook
PTS	Practical Test Standards
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Radio Navigation
RPA	Remotely Piloted Aircraft
RPIC	Remote Pilot in Command
SAE	Society of Automotive Engineers
sUAS	Small Unmanned Aircraft System
UA	Unmanned Aircraft
UAS	Unmanned Aircraft Systems
UMS	Universal Mission Simulator
VCS	Vehicle Control Software
VMC	Visual meteorological conditions
VOR	Very High Frequency Omni Directional Range

DEFINITIONS

Control Station (CS) – FAA Order 8900.1 Volume 16 (FAA, 2017) defines as the structure or system (ground, ship, or air-based) that controls the UAS and its interface to the aircraft and external systems.

Emergency – According to the FAA Pilot/ Controller Glossary, an emergency occurs during a distress or urgency condition FAA, 2017. Usually the result of a systems failure or environmental effects. Distress emergencies are immediately perilous, such as engine failure. An urgent condition is potentially catastrophic in the near future, such as low fuel condition or hazardous weather. (AIM, Chapter 6, para. 6-1-2, FAA, 2016.) For the purposes of this research, the term "abnormal" (or "off-nominal") is included under the definition of an "emergency", as only distress or urgent "abnormal" conditions are considered. Also included is the term "contingency operations" – operations of UA following an emergency. Coordination with ATC is expected to be conducted in the same manner as for manned aircraft during these events. (UAS Contingency Operations Literature Review, FAA, 2016.)

Pilot-in-Command (PIC) – a pilot-in-command will always have responsibility for the unmanned aircraft while it is operating. (UAS Roadmap, para. 1.4.3, FAA, 2013.) The PIC has final authority and responsibility for the operation and safety of the flight. (14 CFR 1.1(1).)

Procedure – a preplanned series of actions (steps) to accomplish a specific end task. Generally, amplified checklist procedures contained in the operator's manual identify procedures for each aircraft.

Standards (Pilot and Crew) - the minimum degree of proficiency to which the task must be performed.

Task – a specific operation that a crewmember is responsible to be able to successfully perform, as exemplified by the FAA's task list in its Practical Test Standards (PTS). Tasks may be divided into two subtypes: 1) Technical tasks – measure the crewmember's ability to plan, preflight, brief, run-up and operate onboard systems and sensors. Flight conditions are not required as a prerequisite. 2) Performance tasks – measure the crewmember's ability to perform in-flight tasks, under specific conditions by control manipulation or control station input.

Unmanned aircraft - an aircraft operated without the possibility of direct human intervention from within or on the aircraft. (14 CFR 107.3). For the purposes of this research, the UA will include those aircraft that exceed the weight of the small UA category or has the capability for beyond visual line-or-sight or IFR operations. A small unmanned aircraft weighs less than 55 pounds on takeoff, including everything that is on-board or otherwise attached to the aircraft. (14 CFR 107.3).

Unmanned Aircraft System (UAS) - An unmanned aircraft system (UAS), comprises of an unmanned aircraft system, control equipment including the control station and data terminal, and support equipment including launcher (if required) spares and consumables.

EXECUTIVE SUMMARY

The Alliance for System Safety of UAS through Research Excellence (ASSURE) conducted research focused on minimum operational procedures used by Unmanned Aircraft Systems (UAS) operators. ASSURE project A10: Human Factors Considerations in UAS Procedures and Control Stations was developed to investigate pilot procedures and operating practices for the purpose of developing recommendations.

This research addressed a need regarding the identification of tasks and procedures used in performing larger than 55 lbs civil UAS operations in the National Airspace System (NAS). A literature review identified current and past practices for developing per-phase-of-flight minimum operating procedures. The entire ASSURE A10 project examined the information needs, environmental needs, and minimum pilot and operational procedures for control stations based upon human factors design considerations and anticipated UAS operations. The research further examined the operational needs control stations must support including the execution of pilot procedures, and how those procedures differed from manned aircraft operations.

The research in this report addresses the portion of A10 related to recommendations for potential operational requirements and pilot procedures. Two research questions supported our investigation of these tasks. They were: 1) What are the minimum pilot procedures needed to operate a UAS in the NAS safely? and 2) What are the potential minimum operating requirements applicable to the operation of a UAS larger than 55 lbs. in the NAS?

The approach used in this research included an examination of existing UAS and manned requirements, practices, and procedures. The team investigated commonalities and differences in procedures, practices, and requirements among different UAS systems and between UAS and manned aircraft operations. Past and current practices were used to develop initial recommended minimum pilot and operating requirements and procedures. Validation of procedures using a universal mission simulator with Multiple Unified Simulation Environment (MUSE) software replicated the Vehicle Control Software (VCS) for control station functionality of unmanned aircraft (UA) control, payload control, communications, data dissemination, and mission planning. The validation considered three types of observations, including: 1) Normal and abnormal procedural performance observations to validate if the recommended procedures were comprehensive and accounted for all potential minimum requirements needed; 2) Contingency procedural observations to validate the completeness of recommended contingency procedures; and 3) User interface observations to validate control station controls, layout, and command and data entry sequences supported all minimum recommended procedures.

This report presents the key results comprised of four pilot and 46 operational minimum recommended procedures necessary for a control station to operate a civil single-engine, fixed-wing, single-pilot-configured UAS flying in beyond visual line-of-sight (BVLOS) conditions.

1. INTRODUCTION

This research provides recommended guidance toward the development of pilot requirements, practices, and operational procedures. Currently, there is no standard for UAS minimum operational requirements and pilot procedures for Control Stations (CS). Based on varying levels of UAS CS automation and design, there is a significant lack of knowledge and understanding regarding a common set of tasks and conditions for UAS pilots performing civil UAS operations in the NAS, and how those procedures may differ from manned aircraft pilot procedures. Operation of UAS from control stations creates new concerns including, control station handoff procedures; lost link control procedures; lost link troubleshooting procedures; establishing procedural roles and responsibilities of crewmembers; duty and rest requirements; minimum flight crew requirements; operations during data link degradation and loss; and operations during periods of decreased sensory cues from aircraft and environment. A common set of operational procedures must be established to safely integrate UAS into the National Airspace System with the same level of safety assurance, which currently exists in the operation of manned aircraft today.

This research was organized into three research tasks as depicted in Figure 1. Research task 1, referred to as PC-1, provided a literature review. Research task 2, referred to as PC-2, served as the development phase of the recommended pilot and operational procedures. Research task 3, referred to as PC-3, validated the recommended operational procedures using a representative human-factor-designed CS capable of operating a UAS applying the research assumptions. The findings from PC-1 became initial recommendations for PC-2. PC-3 validated the procedures from PC-2 using a control station, capable of meeting planned assumptions, in a simulated environment.

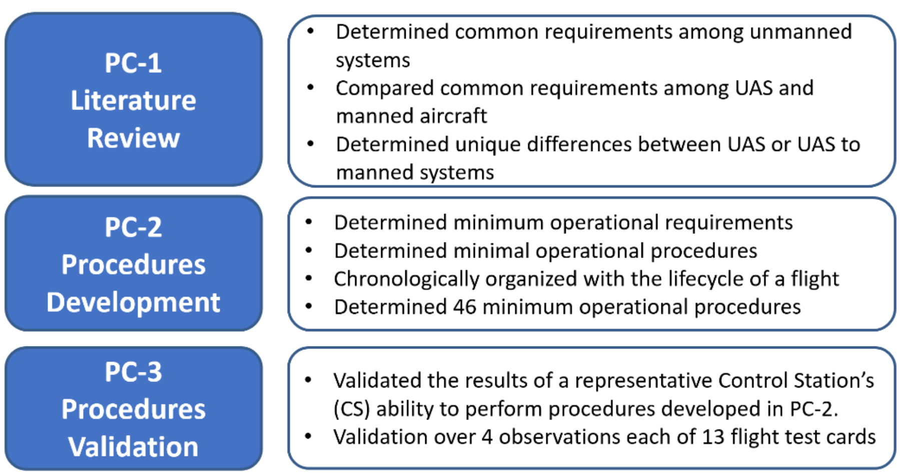

Figure 1. Research tasks flow diagram.

Section 2 describes the assumptions considered for this research. Assumptions were developed to establish a framework for which common recommendations could be made. Section 3 acknowledges limitations of the study to indicate risks that potentially influenced the recommendations for minimum operational needs and pilot procedures. The research questions presented in Section 4, were identified from knowledge gaps about common operational procedures necessary for the development of minimum standards for UAS control stations.

The findings for each component are communicated in this report. Section 5 provides information about existing UAS and manned requirements, practices, and procedures collected during the literature review. Section 6 organizes the minimum recommended pilot and operational procedures, which used current and past practices discovered from the literature review to develop initial recommended minimum pilot and operating requirements and procedures. Section 7 describes the validation processes used in a simulated environment to examine three types of observations including, 1) Normal and abnormal procedural performance observations to validate if the recommended procedures were comprehensive and accounted for all minimum recommendations needed, 2) Contingency procedural observations to validate the completeness of recommended emergency operations, and 3) User interface observations to validate that control station controls, layout, and command and data entry sequences supporting all minimum recommended procedures.

Research Task	Topic	Section
PC-1	Literature Review of Pilot Procedures & Operational Requirements	5
PC-2	Standard Operating Procedures Framework	6
PC-3	Validation Process for the Operating Procedures	7

Table 1. Research task breakout.

Appendices depict information according to research task. The information contained within these appendices comprises individual PC reports previously submitted to the FAA. This information was organized and presented to provide details within a consolidated report, rather than referencing previously submitted reports.

The data provided in Appendix A, collected during the literature review phase of the PC-1 research task, describes commonalities and differences in procedures and practices among different UAS systems and between UAS and manned aircraft. Tasks are organized by phase of flight. Each task was analyzed by 1) common requirements between UAS, 2) common requirements between unmanned and manned aircraft, and 3) unique differences between UAS or UAS and manned aircraft.

The data presented in Appendix B was also collected during the literature review phase of the PC-1 research task. Tasks were aligned with requirements according to the phase of flight. The phase of flight method was selected as a logical approach based on a natural order of flight tasks, which began prior to take-off and completed at engine shutdown after landing.

Appendix C was developed during the validation of requirements and procedures phase of the PC-3 research task. The appendix is organized as an operational procedures matrix with the 46 operational procedures aligned to the 13 flight test cards used in the validation process.

Appendix D presents each of the 13 flight test cards. Each of the flight test cards has four observations. Observations were initially hand written during the data collection process; however, these were transcribed into electronic format in this appendix to communicate observer remarks in this report.

Appendix E presents the results of the validation. Not all operational requirements or procedures were validated using the representative device in a simulated environment because they were independent of the control station. These requirements or procedures were compared to manned and unmanned aircraft requirements and procedures. The recommended minimum operational requirements and procedures focus on high-level needs for UAS pilots such as roles and responsibilities, duty and rest considerations, and minimum recommended requirements served by the role of PIC.

Research Task	Topic	Appendix
PC-1	Comparisons by Phase of Flight	A
PC-1	Initial Recommendations by Task	B
PC-3	Operational Procedures Matrix	C
PC-3	Flight Test Cards with Observed Results	D
PC-3	Validation Results	E

Table 2. Appendix by research task to support recommendations in section 6.

2. ASSUMPTIONS

A series of assumptions relating to a generic fixed-wing unmanned aircraft (UA) with a maximum takeoff weight greater than 55 pounds was considered during this research for defining proposed operational requirements and procedures that apply to a broad set of UAS operations for full-integration into the NAS. These assumptions helped establish proposed operational requirements and subsequent procedures that were derived.

All elements of the system and flight operations were based upon several broad assumptions as to what makes up a UA that is capable of fully integrating into the NAS. These assumptions were as follows:

- The UA had a maximum takeoff weight greater than 55 pounds.
- The UA was a fixed-wing aircraft.
- The UA had a single power plant.
- A crew with a single pilot was required for flight.
- The pilot using the CS controlled a single unmanned aircraft.
- Flight operations were conducted under instrument flight rules (IFR).
- Flight operations were conducted day or night, as dictated by required equipage.
- Flight operations were conducted over people.
- Flight operations took place in airspace classifications D, E, and G, including both towered and non-towered airports.

- Flight operations may take place under varying levels of traffic conditions.

With the above assumptions, additional inferences were made such that the system met requirements to operate in the NAS. Equipage, operating limitations, and operational scenarios were extrapolated from the initial assumptions listed above. This context was used to derive basic operational requirements.

3. LIMITATIONS

The focus of the operational procedures was on civil aircraft operations; however, several public-use UAS were reviewed because of the lack of existing civil UAS operations for aircraft weighing greater than 55 pounds. The primary limitation of the research was the availability of documentation for UAS weighing greater than 55 pounds that were not deemed proprietary by the manufacturer or restricted by International Traffic in Arms Regulations (ITAR) or Export Control requirements.

UAS tasks and standards were compared only to FAA Airplane Single-Engine Land Commercial Practical Test Standards (PTS), Aircraft Certifications Standards (ACS), and relevant tasks in the Instrument ACS. Where there were gaps in the literature that precluded a review of a specific area or type of UAS, future research was suggested. Recommended requirements and procedures for additional crewmembers, such as crew chiefs, visual observers (VOs), and other essential crew were not included in this research.

Based on the assumptions for operations in class D, E, and G airspace varying levels of traffic conditions may require additional requirements or procedures to be developed; however, the procedures recommended in this research were considered the minimum recommendations for varying levels of class D, F, and G airspace with consideration of the PTS and ACS reviewed.

4. RESEARCH QUESTIONS

Consistent with the FAA’s goals for safe integration of civil UAS into the national airspace system, the following research questions were the focus of this investigation to support identification of tasks necessary to identify operational procedures for minimum standards for CSs.

1. What are minimum pilot procedures that a RPIC must execute to operate in the NAS?
2. What are the minimum operating requirements applicable to the operation of a UAS larger than 55 lbs. in the NAS?

5. PC-1 LITERATURE REVIEW

The purpose of PC-1 was to conduct a literature review. The literature review surveyed practices and procedures, developed from industry and the military, to provide direction toward the development of procedures related to unmanned operations. Details supporting the outcomes of the literature review can be found in Appendices A through C.

In reviewing existing procedures, certain characteristics for successful procedures were considered. Research by Degani and Wiener (1997) suggested that a procedure consists of the following: 1) Stating the end task, 2) When the task is conducted, 3) How the task is done (the action steps), and 4) By whom it is conducted (e.g. pilot vs. sensor operator, etc.).

Standardized procedures were essential to store the collective wisdom of the organization and should be logical and efficient. Even though preplanned procedures cannot cover the unimagined emergency, good procedures were the most effective method of disseminating knowledge of proper system operation. In most cases, at a minimum, the pilot must have been able to correctly diagnose the malfunction and apply the appropriate emergency procedure. Also see AC120-71B, Standard Operating Procedures and Pilot Monitoring Duties for Flight Deck Crewmembers, (2017).

PC-1 sampled public and civil use UAS capable of flight under IFR and beyond visual line of sight. Procedures obtained from nine different UAS manufacturers were compared against manned procedures contained in the FAA Airplane Single-Engine Land Commercial Practical Test Standards (PTS), Aircraft Certifications Standards (ACS), and relevant tasks of the Instrument ACS. Each phase of flight was reviewed. The reviewed requirements and procedures available for each selected task were described using the following three statements for clarity: 1) Common practices among UAS, 2) Common practices among UAS and manned aircraft, and 3) Unique differences between UAS or UAS to manned systems.

5.1 LITERATURE REVIEW METHODOLOGY

The literature review was organized according to phase of flight (i.e. preflight, taxi, takeoff, en-route, landing, and after landing) for nominal procedures, and abnormal and emergency procedures. Review of the extant literature indicated many procedures common among the unmanned platforms surveyed as well as many notable differences. Similarities and differences were compared between UAS-to-UAS and UAS-to-manned and it was noted that procedures varied widely between phases of flight. A common observation from the literature review is that unmanned aircraft pilots have adapted to manned standards and procedures as closely as possible when technology and safety have made it possible to do so. However, under circumstances where technology is needed to address the lack of an onboard human pilot, the procedures deviated. Details regarding the UAS-to-UAS and UAS-to-manned procedures can be found in Appendix A.

The research included procedures obtained from manufacturers and operators as well as information from FAA advisory circulars, orders and manuals. Military operational procedures were included because of the lack of existing procedures for the integration of UAS weighing more than 55 pounds in the NAS. Where applicable, foreign sources were included. Effort was made to maintain a civilian vernacular instead of using terms familiar to military operations.

As part of the literature review for commonalities and differences between UAS-to-UAS and UAS-to-manned procedures, a study of other recent publications was conducted. The following four publications were found to beneficial in information and theory:

1. SAE International had published research titled, "Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations". (APR5707, 2010, reaffirmed 2016.) Although this document concerned training and civil pilot certification, it was interesting to note its assumption that final pilot certification standards (even for larger-than-small UAS) did not require any manned aircraft experience. The document stated:

   > Unlike manned flight, the sensory cues upon which pilots relied for information about the state of the aircraft were absent in UA Ground Control Stations (GCS) (Williams, 2008). Seagle (1997, as cited in Thompson, Tvaryanas, & Constable) reported that the lack of sensory feedback may contribute to launch and recovery accidents. In their discussion of sensory feedback as a factor in UA mishaps, Thompson, Tvaryanas, & Constable (2005) suggested that pilots with prior flight experience were more likely to note the absence of sensory feedback. Furthermore, in their investigation of the effects prior flight experience on UA pilot skills, Schreiber, Lyon, Martin, and Confer (2002) stated that their military pilot participants reported that the landing task was quite difficult. The authors suggested that training to "unlearn" some previously acquired piloting skills may be required for experienced pilots transitioning to unmanned aircraft.

2. A review of control station research pursuant to NASA's *Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project* was presented by Fern, Rorie and Shively at the Human Factors and Ergonomics Society 58th Annual Meeting (2014). They had used the Air Force Research Laboratory's (AFRL) Vigilant Spirit Control Station (VSCS) as a prototype control station display suite because it offered the necessary sophistication and was a highly flexible and changeable test bed. Three simulations were completed consisting of: 1) Determining a baseline performance of UAS pilots operating in civil airspace under current instrument flight rules for manned aircraft. 2) Examining the effect of currently employed UAS contingency procedures on Air Traffic Control (ATC) participants. 3) Comparing three CS command and control interfaces on UAS pilot response times in compliance with ATC clearances.

3. A recent study by Hobbs and Lyall (2015) entitled "Human Factors Guidelines for Unmanned
   Aircraft System Ground Control Stations" and conducted under NASA's integration project was released in September, 2015 for review and comment. The study provides preliminary guidelines for control station design for beyond line-of-sight UAS.

   The Hobbs & Lyall study relied upon the assumptions in the FAA UAS roadmap (2013) which had been used to define the responsibilities that were assigned to the pilot of a UAS operating in the NAS. These responsibilities were used to define the tasks that UAS pilots must perform with the CS, and therefore dictated the minimum features a CS must contain. The points of difference between UAS and manned aviation had been used to further focus the guidelines.

4. Another valuable report was "A Review of Training Requirements for UAS, sUAS, and Manned Operations" (Gildea, Williams, and Roberts, 2015). This report was in draft at the time of this review and may change before final release by the FAA. The report was directed

to the study of training requirements, but the methods of comparing training requirements to the FAA Practical Test Standards was useful as tasking and training are crossover areas.

5.2 UAS-TO-UAS OBSERVATIONS

Not all UAS have the same capabilities or design purposes and therefore differences in software complexities and cockpit designs were observed. Despite varying technologies to achieve acceptable levels of safety, recommended minimum operational procedures and minimum requirements were provided. These recommended minimums were considered minimal tasks the UAS pilot needed to perform for safe integration into the national airspace. Details regarding the UAS-to-UAS observations can be found in Appendix A.

UAS control stations varied as widely in operation and configuration as did manned cockpits of the early 20th century. As stated by Hobbs & Lyall (2015), a CS contained controls and displays sourced from diverse commercial off-the-shelf (COTS) providers was likely to suffer from a lack of consistency and potential integration issues. This may result in increased crew training requirements, reduced efficiency, and an increased potential for operator errors.

5.3 UAS-TO-MANNED OBSERVATIONS

There were considerable differences in autonomy assumptions between manned and unmanned aircraft. Although elevated levels of autonomy had been achieved in the "glass cockpits" of manned aircraft, the designs were based on the pilot being able to manually fly the aircraft in the event of electronics failure. This was not a valid assumption for some UAS, as the pilot cannot simply turn off the autopilot and hand-fly the aircraft. There may be no "joystick" or other method of manual control. The removal of the pilot as a backup system to the automated systems was seen as an inherent risk associated with autonomy failure and a difference between manned and unmanned operations. (See Beth Lyall of Research Integrations, Inc., Human Factors and Ergonomics Society, 56th Annual Meeting, 2012.) Details regarding the UAS-to-manned aircraft observations can be found in Appendix A.

The Preflight procedures were similar across manned and unmanned platforms. This was logical because the difference in platforms was of no concern when it came to good airmanship. Unmanned pilots performed planning similar to manned pilots, such as gathering all information available prior to flight to support go/no-go decisions, complete flight planning, as well as ensuring safety was observed. In contrast, large variations were discovered in en-route navigation methods for unmanned aircraft. This may present a potential challenge for operating in the NAS. Differing sources of altitude information were noted (i.e. GPS vs barometric, electronic-map-embedded elevation data). Unless a requirement was set, it was important for pilots to understand what internal and external awareness tools were available and these tools varied compared to manned aircraft operations.

Designation of a single PIC was consistent between all platforms, manned and unmanned; however, crew-changeover procedures presented the unique possibility of the incoming PIC having not been present for, nor having participated in, all phases of flight such as preflight, taxi, takeoff, transfer of control, or en-route operations, while still executing the responsibilities of PIC for the flight's later procedures such as landing. Control Station Handoff procedures among UAS were found to commonly include a requirement for briefings which included current aircraft performance, navigation plan, current ATC clearance, command and control status, and fuel remaining. Some of these hand-over procedures were unique to UAS.

While evaluating the landing phase, the commonality of automated landings appeared unique to UAS as opposed to the literature reviewed for manned aircraft where this concept was less utilized. Missed approaches and go-arounds were assessed to be similar between manned and unmanned aircraft in intent and execution.

There were differences between manned and unmanned operations during failure of navigation systems. UAS technology and platform reliance on internal navigation varied widely, to include redundancy and back-up systems, such that no commonality could be assessed. BLOS aircraft had few operations to bring the aircraft safely back to a landing airfield in the case of loss navigation capability. Another unique difference was noted in that given visual meteorological conditions (VMC), this emergency procedure concluded for manned aircraft upon successfully reaching a landing field. Because of UAS dependence on internal navigation for landing, the same procedures were not observed in unmanned aircraft operations.

There were minimal differences between manned and unmanned operations during taxi operations. After-landing ground support procedures are similar except for the remote communication element often associated with unmanned aircraft operations. After-landing taxi procedures appeared common across manned and unmanned aircraft capable of taxi, because of requirements to coordinate with tower and ground control during these phases. UAS procedures relied upon ground support in many instances adding risk to any taxi operation that a manned pilot may not incur.

5.4 ABNORMAL AND EMERGENCY PROCEDURES

Manned and unmanned emergency procedures were similar when technology differences were minimal. For example, manned aircraft procedures varied from unmanned procedures during periods of intermittent or degraded downlink. In this situation, common considerations among unmanned aircraft included the use of payload video, if available, to confirm uplink health, or in emergency procedures, to navigate the aircraft to a better location, return to home, or navigate to a flight termination location. Another notable difference was a lack of abnormal procedures in unmanned operations compared to manned operations. For unmanned procedures, the procedure was either normal or emergency.

This research highlighted characteristics of some UAS platforms during an emergency based on autonomy design and level of technology. Though both unmanned and manned systems standards and procedures call for the PIC to understand and operate within the performance envelope of their aircraft for an emergency, a unique difference among unmanned aircraft demonstrated the additional need to consider automated triggers. One reviewed UAS automatically shut down the engine upon reaching the Initial Approach Point (IAP) when set in an emergency condition, eliminating the ability to execute a missed approach. Another unique consideration among unmanned aircraft was a potential for a PIC during the en-route phase to be non-current and/or not certified to land the aircraft if an emergency arose.

There were no flight termination procedures or standards for manned aircraft. Commonality was found in emphasis for aircraft ditching locations and the concern about the safety of other aircraft, resources, and people on the ground. This was observed frequently within emergency procedures for unmanned aircraft. It was acceptable to terminate or ditch a UAS that might have been recoverable if indications of any harm were possible to property or lives.

For the most catastrophic emergency, propulsion failure, all UAS's reviewed had an engine failure/engine out checklist or procedure. Most maintained electrical power for aircraft control, navigation and communication. Unlike manned aircraft, most unmanned platforms did not appear to have an in-flight engine restart capability.

Following the advent of federal regulation in aviation, Airplane Flight Manuals (AFM) and Pilots Operating Handbooks (POH) had encapsulated a standard format for FAA approved crew procedures and other information critical for the safe operation of civil aircraft in the NAS. Unmanned operations documentation was subsequently lacking in commonality between manned and unmanned operations as well as variance between UAS. Some UAS lacked an AFM or POH for standardized flight procedures.

6. RECOMMENDED OPERATIONAL REQUIREMENTS AND PILOT PROCEDURES (PC-2)

This section proposes the recommendations for potential operational requirements and pilot procedures. Operational requirements and procedures were derived following the conclusion of the PC-1 literature review. Using the assumptions and information gathered from PC-1, along with input from subject matter experts, the research team generated a series of tasks and associated operational requirements for each phase of flight. The research team then generated the recommended operational procedures for each requirement associated with the tasks within each phase of flight. Procedures were organized under normal, abnormal, and emergency procedure categories where appropriate. The research team then identified minimum requirements and procedures for each task. These recommendations for potential operational requirements and pilot procedures were then validated as part of PC-3. The results from the validation are shown in Appendix F.

For this research, a minimum crew was considered for flight operations. The minimum crew consisted of a RPIC in a single-pilot flight operation without any required support crew. These proposed minimum operational requirements and procedures focused on tasks performed by the RPIC throughout the various phases of flight, from takeoff through landing and final taxi. Proposed requirements and procedures for additional crewmembers, such as crew chiefs, visual observers (VOs), and other essential crew are outside of the scope of this research and were not considered.

6.1 PROPOSED REQUIREMENTS AND PROCEDURES RELATED TO UAS PILOTS

Proposed Minimum Operational Requirement(s)

- The RPIC has the final authority in the safe operation of the UAS per 14 CFR Part 91.3.
- The RPIC must be able to communicate using standardized aviation phraseology and protocol.
- The RPIC must perform all procedures required for the safe operation of the UA in accordance with all applicable regulations. The RPIC must also maintain positional awareness to ensure that right-of-way rules are followed.
- The RPIC must be knowledgeable of and be able to execute emergency procedures.

Proposed Minimum Operational Procedure(s)

- Exercise final authority in the safe operation of the UAS.
- Use standardized phraseology and protocol when communicating.
- Comply with applicable regulations.
- Execute emergency procedures when required.

6.2 DUTY REQUIREMENTS

Proposed Minimum Operational Requirement(s)

- Flight time limitations must be in accordance with the following portions of 14 CFR Part 91.1059:
  - A normal pilot duty period must not exceed 14 hours within a 24 hour period.
  - Flight time for one pilot must not exceed 12 hours within a 24 hour period.

Proposed Minimum Operational Procedure(s)

- Adhere to established duty and rest requirements.
- Do not exceed a 14 hour duty period within 24 hours.
- Do not exceed 12 hours of flight time within a 24 hour period.

6.3 REST REQUIREMENTS

Proposed Minimum Operational Requirement(s)

- Rest requirements must be in accordance with the following portions of 14 CFR Part 91.1059:
- Rest period is defined per 14 CFR Part 91.1057:

> "Rest period means a period of time required pursuant to this subpart that is free of all responsibility for work or duty prior to the commencement of, or following completion of, a duty period, and during which the flight crewmember or flight attendant cannot be required to receive contact from the program manager. A rest period does not include any time during which the program manager imposes on a flight crewmember or flight

attendant any duty or restraint, including any actual work or present responsibility for work should the occasion arise."

- A minimum of 10 hours of rest is required preceding a normal duty period.
- A minimum of 10 hours of rest is required following a normal duty period.

Proposed Minimum Operational Procedure(s)

- Observe rest requirements in accordance with 14 CFR §91.059.
- Rest period is defined in 14 CFR §91.1057.
- Comply with the requirement to get, at minimum, 10 hours of rest prior to the start of a normal duty period.
- Comply with the requirement to get, at minimum, 10 hours of rest following the end of a normal duty period.

6.4 MINIMUM FLIGHT CREW

Proposed Minimum Operational Requirement(s)

- The RPIC shall possess the following qualifications:
  - The RPIC must possess a current UAS airman certification or the equivalent FAA approved airmen certification is required to act as PIC.
  - The RPIC must possess ratings appropriate to the UAS being flown, with a minimum of an instrument rating or an equivalent certification.
  - The RPIC must maintain currency in the same category of UAS being operated and be proficient in the planned phase of flight as well as landing.
  - The RPIC must have instrument currency per 14 CFR Part 61.57(c) and/or 61.57(d).

Proposed Minimum Operational Procedure(s)

- The RPIC must meet all operational requirements outlined above.

Minimum operational requirements and procedures related to flight operations were presented, organized by phase of flight. Since they were minimum recommendations in nature, they form the basis for addressing operational scenarios, from normal flight operations to emergency and abnormal scenarios. Tasks were organized according to phase of flight (i.e. preflight, taxi, takeoff, en-route, landing, and after landing). Each task identified the minimum requirement and minimum procedure.

6.5 PREFLIGHT

6.5.1 Before Entering the Control Station

Proposed Minimum Operational Requirement(s)

- The pilot must be familiar with all available information concerning each flight, including but not limited to, weather, alternate landing sites, ditching locations, flight termination points, NOTAMs, required communication and clearances, and alternate airport fuel requirements.
- During the flight planning process, the pilot is required to take terrain masking into account to prevent loss of the primary command and control link. Lost-link procedures must take terrain into account.
- The pilot must verify that the control station has the required power and reserve that is appropriate for the flight.
- Prior to flight, the pilot should ensure that all control station environmental controls are functioning properly.

Proposed Minimum Operational Procedure(s)

- Consult all relevant weather sources, including but not limited to those in the Aeronautical Information Manual (AIM) 7.1. Consider a preflight weather briefing.
- Determine alternate landing sites.
- Determine acceptable ditching locations that do not pose a risk to persons and/or property.
- Determine flight termination points along the route of flight.
- Determine fuel/power supply requirements for the route of flight, accounting for the required reserve.
- List alternate airfields along the route.
- Ensure the aircraft mission plan matches the mission plan filed with ATC. Thoroughly review all elements of the aircraft flight plan, including fail-safe contingency mission plans.
- Ensure adequate fuel/power supply for the planned mission, including requirements for weather alternates as required.
- Review entire route of flight for appropriate divert, alternate, and emergency airfields and ditch points.
- Consider terrain masking as part of flight planning. This includes lost-link contingencies.
- Ensure sufficient CS power is available for entire duration of operations.
- Ensure functionality of all equipment as required.
- Inspect environmental control systems.

6.5.2 Presets

Proposed Minimum Operational Requirement(s)

- The pilot must inspect the control station for damage and ensure required equipment is functional prior to initiating startup procedures.
- Require the pilot to have all documentation required for flight present and accessible within the control station.

- Any additional ground control equipment required for flight must be powered on and has sufficient reserve power as required prior to the start of preset verification.
- The pilot will verify that the system powered up correctly.
- Maps and navigation data required for flight must be loaded and verified.
- The pilot must finalize the flight plan as part of the preset check and control station configuration.
- The flight plan and any emergency flight plans or contingencies must be verified.
- The pilot must ensure that all command and control equipment is correctly configured for communication with the aircraft.
- The pilot must set voice communication radios to the appropriate frequencies.
- Instrument approach plates, en-route charts, and any required supplements must be in the control station and accessible to the pilot while the UA is in flight.

Proposed Minimum Operational Procedure(s)

- Review CS maintenance logs.
- Resolve open discrepancies, as required.
- Inspect the control station.
- Conduct an inventory of all appropriate publications to include but not limited to:
    - Pilot operating handbook (POH),
    - Checklists,
    - Regulations,
    - Standard operating procedures (SOPs),
    - Aircraft weight and balance,
    - Current FAA chart publications, and
    - Full FAA chart coverage for the route.
- Apply power to all required ground control equipment.
- Verify that the control station and aircraft powered up correctly in accordance with the applicable POH.
- Ensure sufficient CS power is available for entire duration of operations.
- Ensure functionality of all equipment, as required.
- Load and verify all maps and navigation data that are required for flight.
- Create, upload, and set mission plans.
- Ensure that all command and control link equipment, both in the control station and onboard the aircraft is correctly configured for flight.
- Tune all voice communication radios to the appropriate frequencies.
- Verify that all required approach plates, en-route charts, and any required supplements are in the control stations and accessible.

6.5.3 Preflight Checks

Proposed Minimum Operational Requirement(s)

- The pilot must be proficient in checklist usage and have the ability to properly identify aircraft discrepancies. The pilot must also be knowledgeable with procedures for deferring inoperative equipment and proper fuel and aircraft servicing.

- The successful completion of any built-in test (BIT) must be verified by the pilot.
- The correct function of the throttle must be verified as part of preflight procedures.
- The pilot must set and verify the altimeter to the correct setting as part of preflight procedures.
- Inertial Measurement Unit(s) (IMU) function checks must be conducted as part of preflight procedures.
- The correct function of any flight-critical sensors must be verified.
- The command link, including any redundancies, must be verified to function at the required signal strength(s) required for safe operation.
- Two-way communication radios must be checked for correct function.
- Flight controls must be checked for free and correct operation.
- The pilot must verify any inoperative equipment items in the MEL are functional prior to flight.

Proposed Minimum Operational Procedure(s)

- Verify successful completion of any built-in test (BIT).
- Verify the correct function of the throttle control(s) as applicable.
- Set/verify the altimeter.
- Perform IMU function checks.
- If applicable, perform payload function checks.
- Perform a function check on all redundant command link systems. Ensure that all systems function and are able to do so at the levels required for flight.
- Verify correct function of two-way communication radios by performing a radio check with a controlling agency, crew, or visual observer as required.
- Verify flight controls and flight control surfaces are free and correct.
- Verify any inoperative items found on MEL during preflight have been cleared and signed off.

6.5.4 Engine Start

Proposed Minimum Operational Requirement(s)

- Prior to engine start, the pilot must verify that the proper safety equipment, such as a fire bottle, is present and that the area is clear of hazards and/or non-essential personnel.
- Engine starting procedures must be communicated and coordinated between the pilot, applicable ground control element, and any required ground crew.
- The pilot or other required crewmember must be able to properly perform the engine start procedures.
- Engine health indications must be monitored by the pilot during and after the completion of the engine start procedure.
- Prior to takeoff, the pilot must verify proper operation of the engine and engine indication instrumentation/displays.
- The pilot must be knowledgeable on how to perform abnormal engine start procedures.
- The pilot and ground crew must have a means to command the immediate shutdown of the UA engine in the event of an emergency.

Proposed Minimum Operational Procedure(s)

- Coordinate with crew/applicable personnel to ensure that required safety equipment is present and that the area is clear of hazards and non-essential personnel.
- If applicable, establish communication with appropriate ground control element and ground crew to coordinate engine start procedure.
- Ensure that the system is properly configured for engine start and begin engine start procedures.
- Monitor engine health throughout the engine start procedure.
- Verify proper operation of the engine and all engine instrumentation.
- If applicable, perform abnormal engine start procedures.
- In the event of an emergency during engine start, perform an emergency engine shutdown.

6.5.5 Pre-Taxi

Proposed Minimum Operational Requirement(s)

- If applicable, the pilot must coordinate with ground crews to ensure the airframe is free of frost and/or ice prior to taxi.
- At airports with an operating control tower or ground control element, or where separation from ground traffic cannot be ensured by the pilot, a crewmember must communicate with ATC to receive taxi instructions.
- At airports without an operating control tower, the pilot must communicate with other aircraft and/or utilize observers (as required) to ensure adequate traffic separation during taxi.
- Prior to the start of taxi, all flight-critical avionics must be correctly set and configured.
- All essential crewmembers must be aware of the following:
  - Taxi route,
  - Known hazards along the route, and
  - Contingencies.

Proposed Minimum Operational Procedure(s)

- Verify that the UA is free of frost and/or ice.
- If applicable, contact ATC and request taxi clearance/instructions. If at a non-towered airport, communicate with other traffic on common traffic advisory frequency (CTAF) and/or utilize visual observers or other available means to ensure separation from traffic during taxi.
- Check all critical instrumentation for correct settings including but not limited to the altimeter, navigation equipment, radios, etc.
- Ensure all flight displays are correctly set and configured for flight.
- Brief any participating crewmembers on the following:
  - Taxi route,
  - Known hazards along the route, and

- Contingencies to address any abnormal or emergency situations.

6.6 TAXI

6.6.1 General Tasks

Proposed Minimum Operational Requirement(s)

- The pilot must verify that command and control data links are functioning within operational limits for taxi.
- If brakes are installed, the pilot must perform a brake check to verify proper function of aircraft brakes and brake indications.
- If the UA is capable of being taxied, a loss of data link during taxi operations shall result in the autonomous stopping of taxi operations until the link can be regained.
- If the UA is so equipped, the pilot must be able to taxi with the assistance of visual aids or markers to indicate the correct route.
- If a marshaller is used, the pilot must maintain two-way communications with the marshaller, and if possible, maintain visual contact.
- If a marshaller is used, taxi operations must be conducted at a pace to be set by the marshaller.
- The pilot must be able to recognize and react to hazards on the taxiway, such as other traffic and personnel with the help of a visual observer.
- If the pilot uses full motion video to taxi and no visual observer is utilized to assist, the pilot must bring the UA to a stop if visual contact with the taxiway centerline is lost and cannot be regained in a reasonable amount of time.
- The UA must be taxied at a speed that will allow the pilot to stop the aircraft within a safe distance of traffic and obstacles.
- The pilot must maintain communication with ground control (when applicable) and any applicable ground crew to be able to bring the UA to a stop at any time with a command.

Proposed Minimum Operational Procedure(s)

- Verify that command and control data links have the required signal strength and reliability required for taxi.
- If brakes are installed, perform a check of brake function to ensure the UA may be stopped at any point during taxi. If applicable, utilize ground crew to verify brake function.
- If applicable, contact the ground control element if link is lost during taxi.
- Utilize visual aids and markers to assist with taxi operations to the maximum extent possible.
- If possible, maintain two-way communication with a marshaller, if one is used.
- Conduct taxi operations at the pace of the marshaller or visual observer.
- When using full-motion video, stop UA if runway centerline is lost and contact cannot be regained in a reasonable amount of time.
- Set taxi speed such that the UA is able to be brought to a stop within a safe distance of obstacles and other traffic.

- Maintain communication with ground control and/or applicable ground crew throughout taxi.

6.6.2 Communications

Proposed Minimum Operational Requirement(s)

- All communications must be accomplished using standard aviation phraseology.
- Upon starting taxi operations, the pilot must maintain a sterile cockpit, restricting communication to that which is directly related to the operation of the UA.
- The pilot should have an alternative means of communication available to them within the control station (cellular phone, backup radio system, etc.).

Proposed Minimum Operational Procedure(s)

- Communicate using standard aviation phraseology.
- Maintain sterile cockpit while taxiing.
- Use backup communications during primary communications failure.

6.6.3 Pre-Takeoff Checks

Proposed Minimum Operational Requirement(s)

- Checklists required for takeoff must be completed by both the pilot and any required supporting crew prior to takeoff.

Proposed Minimum Operational Procedure(s)

- Complete any remaining pre-takeoff checks prior to taking position on the runway.

6.7 TAKEOFF

6.7.1 Communications

Proposed Minimum Operational Requirement(s)

- All communication with ATC or controlling agencies must utilize standard aviation phraseology and adhere to standard ATC "read-back" requirements. The pilot must also demonstrate understanding of takeoff, line up and wait, and hold clearances.
- Communication and coordination with ATC is required prior to takeoff. Standard instrument flight communication protocols apply as appropriate.
- Contingencies for the loss of communication and the command link must be in place and able to be executed autonomously or by the pilot prior to initiating a takeoff procedure.

Proposed Minimum Operational Procedure(s)

- Obtain ATC clearance in accordance with procedures in AIM Section 4.
- Record clearances in accordance with AIM 4-4-7a.
- Use backup communications during primary communications failure.

6.7.2 Takeoff Run/Launch

Proposed Minimum Operational Requirement(s)

- Prior to takeoff, the pilot must perform a final check of all flight critical systems such as the control surfaces, communication system(s), data link(s), engine instrumentation, and other essential systems to ensure proper configuration for takeoff.
- A takeoff must not be performed unless it can be verified that the flightpath is clear of traffic.
- Pilots must acknowledge takeoff clearances using standardized ATC communication protocols.
- The following must be monitored during the UA takeoff run:
  - The UA maintains the runway heading.
  - The UA power plant is operating at takeoff power and within normal operating parameters.
  - There are no failures with the navigation system, communications, command and control link, or any other flight-critical systems.
- A refused takeoff should be considered in the event of a flight-critical system failure.

Proposed Minimum Operational Procedure(s)

- Perform flight checks of any critical systems. Verify proper setting and strength of required command link(s).
- Verify traffic is clear.
- Acknowledge receipt of clearance using standard phraseology and read-back practices.
- Maintain runway centerline and runway heading at rotation.
- Maintain takeoff power and monitor critical power plant operating parameters.
- Monitor flight-critical systems, including by not limited to:
  - Navigation system,
  - Two-way communications,
  - Detect, sense and avoid equipment, as applicable
  - Command and control link, and
  - Any other flight-critical systems/equipment.
- Consider takeoff abort if an emergency situation develops.

6.7.3 Initial Climb Out

Proposed Minimum Operational Requirement(s)

- The pilot must be knowledgeable of UA takeoff and climb speeds as they apply to the performance of the UA. Climbs must be performed as appropriate for obstacle clearance.
- When applicable, takeoff climbs must conform to ATC clearance.

Proposed Minimum Operational Procedure(s)

- Rotate at rotation speed (V_R or V_{ROT}).
- Maintain the appropriate V-speed during climb out.
- Maintain ATC-instructed departure altitudes and headings, as applicable.

6.7.4 Aborted Takeoff

Proposed Minimum Operational Requirement(s)

- The pilot must be able to recognize and properly react to safety-critical failures during takeoff and initial climb.
- The pilot must not fly below the minimum required airspeed at which the UA may be controlled.
- Obstacles and hazards in and surrounding the airport environment must be known to the pilot, which must include at a minimum, the available runway and obstacles within 30° of the runway heading.
- Aborted takeoffs must be communicated to ATC as soon as practical.

Proposed Minimum Operational Procedure(s)

- Maintain an airspeed that allows positive control of the UA.
- Maintain a heading that is clear of obstacles.
- Communicate the aborted takeoff to ATC as soon as practical.

6.8 CLIMB TO ALTITUDE

6.8.1 General Tasks

Proposed Minimum Operational Requirement(s)

- The pilot must operate two-way radio equipment as required.
- The pilot must verify the aircraft is configured properly for climb.
- The pilot must maintain assigned heading.
- The pilot must level off at the assigned altitude.

Proposed Minimum Operational Procedure(s)

- Maintain contact with ATC and perform frequency changes as requested.
- Ensure that the aircraft is configured for climb.

- Maintain heading assigned by ATC unless cleared to deviate or climb/maneuver at pilot's discretion.
- Level off at the assigned altitude.

6.9 EN-ROUTE OPERATIONS

6.9.1 General Tasks

Proposed Minimum Operational Requirement(s)

- The pilot must use proper communication procedures when utilizing radar services.
- The pilot must comply with ATC clearance and advise if unable to do so.
- The pilot must respond to ATC clearances using standard readback procedures.
- The pilot must obtain an ATC clearance, as required.
- The pilot must communicate using standard aviation phraseology.
- The pilot must set navigation systems and transponder codes in compliance with the ATC clearance.
- The pilot must establish two-way communication with the proper controlling agency.
- The pilot must identify, assess, and mitigate risks encompassing icing conditions.
- The pilot must perform operations checks as required. These checks will include fuel level, oil temperature, engine operation (or propeller pitch operation), electrical, datalink, and other engine parameters.

Proposed Minimum Operational Procedure(s)

- Use proper communication procedures when using radar services (as applicable).
- Obtain ATC clearance.
- Respond to ATC clearance.
- Comply with ATC clearance.
- Use standard aviation phraseology when communicating with ATC.
- Set navigation systems, and transponder codes to ensure compliance with ATC clearances.
- Conduct any required communication frequency changes.
- Use available systems (if equipped) to detect icing conditions.
- Monitor aircraft electrical, propulsion, and datalink performance.

6.9.2 Navigation (Including GPS Availability)

Proposed Minimum Operational Requirement(s)

- The pilot must maintain awareness of the airplane's position using the available and appropriate navigation system(s).
- The pilot must intercept and track a given course, radial, bearing, or navigational reference as equipped.
- The pilot must recognize navigation signal loss and take appropriate action.
- The pilot must maintain the assigned altitude(s) and heading(s).

- The pilot should follow the preplanned course by reference to steerpoints/waypoints or other available navigational references as appropriate.
- The pilot should identify landmarks by relating surface features to chart symbols, if equipped.
- The pilot should navigate by means of precomputed headings, groundspeeds, and elapsed time, as applicable.
- The pilot should account for the effect of wind on maintaining desired route of flight and its effect on performance.
- The pilot should verify the aircraft's position with respect to the planned flight route.

Proposed Minimum Operational Procedure(s)

- Monitor aircraft's position throughout the flight and maintain course in accordance with ATC instructions/clearance.
- Intercept and track a given course, radial (if equipped), or bearing, as appropriate.
- Determine loss of GPS or primary navigation if it occurs.
- Maintain the appropriate altitude and headings.
- Maintain course by reference to established waypoints/steerpoints or other navigational references, as applicable.
- If equipped, be able to identify surface features to chart symbols.
- If applicable, navigate by means of precomputed headings, groundspeeds, and elapsed time.
- Correct for wind to maintain desired route and performance.
- Remain within planned route described in the flight plan.

6.9.3 En-route Climb

Proposed Minimum Operational Requirement(s)

- UA climb performance information must be known to the pilot, must be published in the UAS POH, and available in the control station. This information must include:
  - Absolute ceiling,
  - Service ceiling,
  - Climb performance based upon pressure altitude and temperature, and
  - Time, fuel, and distance to climb
- ATC must be notified if unable to climb at a specified rate/gradient or to an assigned altitude.

Proposed Minimum Operational Procedure(s)

- Conduct en-route climbs according to ATC clearance.
- Conduct climbs with respect to UA performance limitations, including but not limited to:
  - Absolute ceiling,
  - Service ceiling,
  - Altitude and temperature, and
  - Time, fuel, and distance to climb.

- Notify ATC if the UA is unable to climb at a specified rate or gradient in accordance with AIM 4-4-10(d).

6.9.4 En-route Course Change

Proposed Minimum Operational Requirement(s)

- Course changes must conform to ATC clearance, as required.
- The pilot must command the UA to fly the assigned heading to achieve a desired course.
- The pilot must verify the UA is flying the correct heading to achieve the desired course.
- The pilot must make corrections to maintain a desired course, as required.

Proposed Minimum Operational Procedure(s)

- Obtain and/or acknowledge clearance to change course from ATC.
- Command the UA to fly the desired heading or course.
- Verify the UA is flying the commanded heading and/or course using available flight data.
- Make corrections to maintain heading and/or course as required.

6.9.5 En-route Descents

Proposed Minimum Operational Requirement(s)

- UA descent performance limitations must be known to the pilot. This information must be published in the UAS POH and available to the pilot in the control station.
- UA performance and operating limitations must be known to the pilot. This information must be published in the POH and available to the pilot in the CS.

Proposed Minimum Operational Procedure(s)

- Conduct descents in accordance with ATC clearance.
- Conduct descents with regard to UA limitations.
- Do not exceed UA performance limitations in descents.

6.9.6 Cruise Power Settings

Proposed Minimum Operational Requirement(s)

- Aircraft fuel levels must be monitored while in flight, and power at cruise must be set to achieve the desired performance for the planned flight.
- Computations for propulsion power settings at cruise must take the required fuel/battery reserve into account.
- Cruise performance and fuel levels must be re-computed should airspeed, altitude, and other variables be changed en-route.
- The pilot must be able to determine new performance capabilities/limitations if a flight plan is altered due to change in purpose of flight or emergency.

Proposed Minimum Operational Procedure(s)

- Monitor UA fuel/battery status while in flight.
- Adjust power settings as required to maintain desired performance.
- Perform fuel burn/battery life calculations such that the destination is reached with the required fuel/battery reserve remaining.
- Re-evaluate performance data as required to reach the destination at the required time with the required fuel/battery reserves.
- Determine any new performance capabilities or limitations that may result from alterations in the flight plan or an in-flight emergency.

6.9.7 Weather Monitoring

Proposed Minimum Operational Requirement(s)

- The pilot must be aware of weather conditions along the route of flight.
- The pilot must be aware of meteorological conditions that allow for the formation of airframe icing and utilize anti/de-icing systems as required.
- Hazardous weather along the route of flight must be avoided whenever possible. The pilot must coordinate to avoid potentially hazardous weather wherever possible.

Proposed Minimum Operational Procedure(s)

- Monitor weather conditions along the route of flight, establishing communications with in-flight weather services as required.
- Determine if icing conditions exist and utilize anti/de-icing equipment as appropriate.
- When necessary, alter the flight plan to avoid weather that poses a hazard to the safety of flight.
- Notify ATC if a flight plan must be altered to avoid hazardous weather.

6.10 DESCENT FROM CRUISE

6.10.1 General Tasks

Proposed Minimum Operational Requirement(s)

- The pilot must conduct descents in a manner that does not impede or decrease the safety of other air traffic
- The pilot must coordinate with ATC if using non-standard approach procedures.
- If applicable, the pilot must adhere to ATC clearances during descent.
- The pilot must ensure that the UA is configured for descent.

Proposed Minimum Operational Procedure(s)

- Descend to pattern altitude or an approach fix/initial approach waypoint in a manner that does not impede or decrease the safety of other air traffic.
- If unable to perform a published instrument approach, coordinate approach procedures with ATC prior to arrival at the initial approach fix.
- If applicable, comply with ATC clearance to descend.
- Ensure that the UA is configured for descent.

6.11 APPROACH

6.11.1 General Tasks

Proposed Minimum Operational Requirement(s)

- Airspeed, altitude, heading, and system health parameters must be monitored while on approach.
- Instrument approaches must be performed per the published approach procedures unless a standardized alternative is available.
- If a visual observer is the sole means of verifying and clearing the landing path, ensure that two-way communication is established prior to initiating the approach.

Proposed Minimum Operational Procedure(s)

- Monitor the airspeed, altitude, heading, and system health parameters while on approach.
- Perform approaches per the published approach plates unless a standardized approach exists for specific unmanned system being flown.
- Ensure that the final approach path is clear of aircraft and obstacles.
- If a visual observer (VO) is the sole means of clearing the airspace for an approach, ensure that two-way communication with the observer is maintained throughout the approach.

6.12 LANDING

6.12.1 Communications

Proposed Minimum Operational Requirement(s)

- Two-way communication must be established prior to arrival at the destination or when passing through controlled airspace. Communications with the controlling agency must be maintained while the UA is in controlled airspace.
- Communication during landing procedures must conform to standardized aviation phraseology and be appropriate to the airspace in which the UA is operating.

Proposed Minimum Operational Procedure(s)

- Establish communication with local ATC when arriving at the destination or entering controlled airspace, as applicable.
- Maintain communication with ATC when operating in controlled airspace. Acknowledge and read back clearances per the AIM 4-4-7(b).
- Use standard phraseology to obtain ATC clearance for landing.

6.12.2 Approach and Landing (Human-in-the-Loop)

Proposed Minimum Operational Requirement(s)

- The pilot must be trained in all applicable landing procedures.
- The pilot must obtain clearance from ATC to land.
- The pilot must ensure that the UA is configured for landing.

Proposed Minimum Operational Procedure(s)

- Choose landing procedure appropriate to the type of approach and prevailing weather conditions.
- Contact ATC and request clearance to land; acknowledge landing clearance when received.
- Ensure that the UA is configured for landing prior to touchdown.

6.12.3 Go-Around

Proposed Minimum Operational Requirement(s)

- When considering executing a go-around, the pilot must assess the risk posed by continuing to land when compared to the risk associated with the aborted landing.
- Intent to perform a go-around must be communicated to ATC as soon as it is practical to do so.
- Go-around maneuvers must be executed at appropriate engine power settings to achieve a climb gradient that allows the UA to remain clear of obstacles.
- Upon initiating a go-around, the UA must climb to a predetermined altitude that allows for obstacle clearance.
- In the event of a go-around, the pilot must follow published missed approach procedures and/or ATC clearance to re-attempt the approach.

Proposed Minimum Operational Procedure(s)

- Communicate the go-around to ATC as soon as practical.
- Abort landing prior to commitment point.
- Maintain positive rate of climb.
- Maintain runway centerline.
- Climb to a predetermined altitude that ensures obstacle clearance.
- Follow applicable missed approach procedures.

- Coordinate with ATC as required to re-attempt the approach.

Recommended Operational Procedure(s)

- Assess the risk of performing a go-around.

6.12.4 Ground Support

Proposed Minimum Operational Requirement(s)

- If required for landing, ground support personnel must adhere to standardized procedures to ensure operational safety and be properly briefed on required procedures.

Proposed Minimum Operational Procedure(s)

- If required for landing, coordinate with any ground support personnel and brief them on landing procedures.

6.12.5 Approach and Landing (Automated)

Proposed Minimum Operational Requirement(s)

- Automated landings must be monitored by the pilot to ensure that the aircraft adheres to performance limitations and approach parameters throughout the maneuver.
- The pilot must be able to interrupt an automated approach and landing in the event of an emergency or to input corrections as needed to ensure a safe landing.

Proposed Minimum Operational Procedure(s)

- Monitor the aircraft on approach and ensure that it conforms to known performance limitations on approach and landing.
- If required and the UA is so equipped, make manual control inputs to assist in guiding the UA while on approach.
- If applicable, assume manual control of the UA in the event of an emergency.

6.13 POST-LANDING

6.13.1 Communications

Proposed Minimum Operational Requirement(s)

- Communication must be maintained with ATC or the required controlling agency upon landing. The pilot must be prepared to follow instructions relating to taxi, route of taxi, and holding short for traffic.

Proposed Minimum Operational Procedure(s)

- Maintain communication with the applicable ATC element upon landing.
- Follow ATC instructions for taxi.

6.13.2 Taxi

Proposed Minimum Operational Requirement(s)

- Communication and coordination with ATC and any required ground crew must be maintained when taxiing clear of the runway.
- When taxiing clear of the runway, the pilot must have the ability ensure that the UA remains clear of obstacles, vehicles, and other aircraft.
- The pilot is required to observe and comply with all signage and warning lights, if equipped. If not equipped to visually identify signage and warning lights, the pilot must follow instructions from ground crew or ground control element to the maximum extent they are able.

Proposed Minimum Operational Procedure(s)

- Taxi on cleared route.
- If capable of taxi, maintain a taxi speed at the marshaller's pace, or as appropriate to maintain separation from other traffic.
- Remain a safe distance from other aircraft.
- Avoid hazards on taxiway surface.
- Taxi according to applicable signage and warning lights.

6.13.3 Ground Support

Proposed Minimum Operational Requirement(s)

- When applicable, the pilot must coordinate with ground support personnel to park the UA.
- Engine shutdown must be completed in accordance with applicable procedures. A post-flight inspection must be conducted following engine shutdown.
- If applicable, engine shutdown must be confirmed with crew.

Proposed Minimum Operational Procedure(s)

- Verify UA is parked in designated location.
- Shut down the engine.
- If applicable, confirm engine shutdown with ground crew.
- Perform a post-flight inspection of CS and associated systems.
- If applicable, coordinate with ground crews to perform a post-flight inspection of the UA.

6.14 CONTROL STATION HANDOFF

6.14.1 General Tasks

Proposed Minimum Operational Requirement(s)

- If a control station handoff is intended as part of the flight plan, the correct function of the receiving control station(s) must be verified prior to initiating handoff procedures.
- Prior to initiating control station handoff procedures, the pilot must establish two-way communications with the receiving control station.
- Control station handoffs must be performed procedurally. Positive transfer of control must be confirmed between pilots every time a control station handoff occurs.
- Control station handoff briefings must include, at minimum:
  - UA health,
  - Fuel state,
  - Altitude,
  - Airspeed,
  - Heading,
  - ATC clearances,
  - Any abnormal occurrences,
  - Any information deemed safety critical by the pilot that is handing over control,
  - Confirmation of command link integrity (strength/reliability), and
  - Lost-link profile(s)/routing.
- Control station changeover briefings must include, at minimum:
  - UA health,
  - Fuel state,
  - Altitude,
  - Airspeed,
  - Heading,
  - ATC clearances,
  - Any abnormal occurrences,
  - Any information deemed safety critical by the pilot that is handing over control,
  - Confirmation of command link integrity (strength/reliability), and
  - Lost-link profile(s)/routing.

Proposed Minimum Operational Procedure(s)

- Receiving Pilot - Perform preflight on receiving CS and verify correct function of essential systems.
- Establish two-way communication with the receiving control station prior to initiating a control station handoff.
- Receiving CS: Establish voice communications with transferring CS.
- Receiving CS: Coordinate with transferring CS to establish C2 link with UA, if/as applicable per the pilot's operating handbook (POH).
- Transferring CS: Provide handover briefing to Receiving CS:
  - Verify autopilot mode,

- If applicable, verify matched commands,
- If applicable, verify data terminal settings,
- Verify altimeter setting,
- Verify current clearance, and
- Verify any other flight-critical systems.

➢ Transferring CS: Initiate positive transfer of UA control to Receiving CS.
➢ Receiving CS: Verify UA control.
➢ Keep the transferring CS on link as a backup, if/as applicable.
➢ For transfer of UA control from one CS to another – Perform a control station handoff briefing for the receiving pilot, to include at a minimum:
- UA overall health,
- Fuel state,
- Altitude,
- Altimeter setting,
- Airspeed,
- Heading,
- ATC clearances,
- Any abnormal occurrences,
- Contingency/emergency plan(s),
- Safety critical information that the receiving pilot will need to ensure safe flight, and
- Confirmation of command link integrity (strength/reliability).

➢ For an internal crew changeover within a CS– Perform a crew changeover briefing for the receiving pilot, to include at a minimum:
- UA overall health,
- Fuel state,
- Altitude,
- Altimeter setting,
- Airspeed,
- Heading,
- ATC clearances,
- Any abnormal occurrences,
- Contingency/emergency plan(s),
- Safety critical information that the receiving pilot will need to ensure safe flight, and
- Confirmation of command link integrity (strength/reliability).

6.15 LOST-LINK CONTROL PROCEDURES

6.15.1 General Tasks

Proposed Minimum Operational Requirement(s)

➢ UA lost-link behavior must consist of one or more predetermined flight plans that are activated automatically upon the loss of the command link. The pilot must understand how the UA will behave in the event lost-link flight plans are activated. Lost-link behavior must also trigger an appropriate transponder squawk code to alert ATC of the UA's lost-link status.

- If able, the pilot must communicate with ATC to verify the appropriate transponder squawk code upon encountering a lost-link scenario.
- Upon encountering a lost-link scenario, the pilot must communicate the UA's last known altitude, heading, destination, location, and expected lost-link behavior/routing to ATC.

Proposed Minimum Operational Procedure(s)

- Ensure that lost-link fail-safes are set up as appropriate for the flight (including any automated transponder triggering to squawk 7400) and active throughout all phases of flight.
- Communicate lost-link behavior to ATC and verify appropriate transponder squawk code, if able.
- At a minimum, relay the following information to ATC:
    - Last known altitude,
    - Heading,
    - Destination,
    - Location when the link was lost (Latitude/Longitude), and
    - Expected lost-link behavior/routing.

6.16 LOST-LINK TROUBLESHOOTING PROCEDURES

6.16.1 General Tasks

Proposed Minimum Operational Requirement(s)

- The pilot should communicate the outcome of lost-link troubleshooting procedures to ATC upon completion of the lost-link troubleshooting checklist.
- Lost-link troubleshooting procedures must be published in the UAS POH and accessible by the pilot in the control station.
- Lost-link troubleshooting procedures must clearly define instances when the flight may be continued or must be terminated.

Proposed Minimum Operational Procedure(s)

- Refer to published troubleshooting procedures when troubleshooting a lost command link.
- Continue or terminate the flight based upon the outcome of link troubleshooting procedures.
- Communicate the outcome of troubleshooting to ATC.

6.17 OPERATIONS DURING COMMAND AND CONTROL LINK DEGRADATION AND LOSS

6.17.1 General Tasks

Proposed Minimum Operational Requirement(s)

- Command link integrity must be monitored while in flight, and should degraded performance be encountered, the pilot must take steps troubleshoot command link performance if it is deemed necessary to do so.
- Operations during command and control degradation and loss must be included in the POH. Procedures must address:
  - Troubleshooting measures that must be undertaken by the pilot to restore control,
  - Communication protocols, including communications/coordination with ATC,
  - Actions to be taken if the command link is re-established or restored to full functionality, and
  - Contingencies for degraded operation.

Proposed Minimum Operational Procedure(s)

- While operating a UA, monitor the command and control link integrity. Should degraded link performance be encountered, execute appropriate procedures to address the situation.
- During command and control degradation or loss of signal, execute appropriate checklists, troubleshooting, communication protocols, and contingencies for re-establishing the command link.

6.18 OPERATIONS DURING PERIODS OF DECREASED SENSORY CUES FROM AIRCRAFT AND ENVIRONMENT

6.18.1 General Tasks

Proposed Minimum Operational Requirement(s)

- If equipped, the pilot may utilize aircraft sensors, such as electro-optical cameras, infrared sensors, or any other available means to regain or maintain orientation and spatial awareness.
- If required for safe operation, the pilot must be able to manage multiple telemetry datalinks independently.
- The pilot must be able to interpret information from multiple instruments and displays to determine the UA's status.
- The pilot must be able to prioritize emergency procedures in the event that multiple emergency scenarios occur when in a state of degraded sensory cues.
- To facilitate navigation in situations where cues from the UA are intermittent or degraded, the pilot must be able to use recorded position, heading, and airspeed to calculate the proper heading and time to a designated recovery point.
- If equipped with a directional ground data terminal (GDT), the pilot must be able to use GDT azimuth and dead reckoning icons to aid in navigation and maintain UA position.
- The pilot is required to understand when conditions of partial or full loss of sensory cues exist.

Proposed Minimum Operational Procedure(s)

- Determine if full or partial loss of sensory cues exist.
- If applicable, use UA sensors to regain or maintain orientation and spatial awareness of the UA.
- If applicable, manage multiple telemetry datalinks independently.
- Maintain positional and spatial awareness of the UA by scanning displays and instrumentation.
- Monitor UA caution/alert status.
- If multiple emergences exist, manage them using aeronautical decision making techniques.
- When applicable, calculate position, headings, and airspeed to determine proper heading and time to designated location.
- If equipped, be familiar with ground data terminal azimuth and dead reckoning to maintain UA position.

Recommended Operational Procedure(s)

- Determine if full or partial loss of sensory cues exist.

6.19 IN-FLIGHT EMERGENCIES

6.19.1 Propulsion Failure

Proposed Minimum Operational Requirement(s)

- Propulsion failure notifications must be available to the pilot and must convey any associated system failures that aid the pilot in diagnosing the failure.
- The pilot must maintain aircraft control and properly configure the aircraft to achieve an optimum glide.
- Emergency landing areas must be selected such that risk to personnel and property on the ground and in the air is minimized.
- Emergency approaches and landings that transect high-volume airspace should be avoided whenever possible.
- If no suitable landing airfield is available, the pilot must determine the best area to ditch or terminate aircraft.
- Terrain and weather conditions must be evaluated when choosing a suitable emergency landing or ditching location.
- Utilize applicable emergency procedures to address an engine failure.
- The pilot must set the transponder to squawk 7700 in the event of an engine failure, if able.
- When the situation warrants, the pilot must communicate engine failures to ATC.
- The pilot must coordinate with ground support personnel as necessary to meet the needs of an emergency.

Proposed Minimum Operational Procedure(s)

- Identify and address engine failure notifications with the appropriate emergency procedures, as applicable.
- Maintain aircraft control and configure the aircraft to achieve optimum glide, as required.
- While performing an emergency landing, select landing areas that pose minimal risk to personnel and property on the ground.
- During an emergency landing, take high-volume transects and approaches into consideration and maneuver to avoid them whenever possible.
- If a suitable landing site is unavailable, determine the best area to terminate the flight to minimize risk to personnel and property on the ground.
- Determine effects of weather on landing/ditching location.
- Address all applicable emergency procedures as practical.
- Set transponder to 7700 if/when able to do so.
- Communicate an engine failure to ATC as soon as practical.
- When applicable, notify ground crew.

6.19.2 Two-way Communications Failure

Proposed Minimum Operational Requirement(s)

- When feasible, the pilot should ensure UA transponder squawk code is set to 7600.
- When available, the pilot should use an alternative means of communication, such as a cellular phone, backup radio system, or some other means to communicate with ATC in the event of a communication failure.
- When the UA is so equipped, the pilot must prioritize routing as follows:
    - Assigned route,
    - Vectors,
    - Expected (if given further clearance), and
    - Filed flight plan.
- When applicable, the pilot must prioritize altitude as follows:
    - Assigned altitude,
    - Expected altitude (if given further clearance), and
    - Minimum en-route altitude (MEA).

Proposed Minimum Operational Procedure(s)

- Set transponder to 7600.
- When available, utilize alternative means of communication to communicate with ATC.
- Prioritize routing as required for IFR communications failures.
- Prioritize altitudes as required for IFR communications failures.

6.19.3 Navigation Failure – GPS or Other System

Proposed Minimum Operational Requirement(s)

- The pilot must diagnose navigation failures and take timely action to troubleshoot them.
- In the event of a failure within the navigation system, the pilot must address the failure(s) in accordance with established procedures.
- In the event of a navigation failure, the pilot must maintain radio contact with ATC. If the UA is not capable of safely continuing the flight or landing safely, the pilot must contact ATC and advise of intent.
- If applicable, the pilot should utilize dead reckoning navigation.
- Standard procedures for off-site landings must be published, known to the pilot, and accessible to the pilot within the control station.

Proposed Minimum Operational Procedure(s)

- Address navigation system failures as soon as practical.
- Address a navigation failure in accordance with established procedures for the given system.
- If applicable, perform dead reckoning navigation.
- Notify ATC of intentions.
- Refer to off-site landing (ditching) or termination procedures, as required, if flight cannot be continued with a failed navigation system.

6.19.4 Detect and Avoid (Traffic, Terrain, and Obstacles)

Proposed Minimum Operational Requirement(s)

- The pilot is required to give way to both manned and unmanned aircraft per 14 CFR §91.113. The pilot should use their discretion when acting upon alerts from collision avoidance instruments including but not limited to TCAS, ADS-B, and TIS.
- If an automated detect and avoid system is used, it must give way to other air traffic in a manner that is consistent with 14 CFR §91.113.
- Potential collision threats must be displayed to the pilot.
- The pilot must be able to execute evasive maneuvers when required.
- If autonomous detect and avoid systems are used, the pilot must be able to monitor the execution of collision avoidance maneuvers.
- The pilot must be able to override autonomous collision avoidance maneuvers.
- When able, the pilot must communicate with ATC upon deviating from a clearance to execute a collision avoidance maneuver.

Proposed Minimum Operational Procedure(s)

- Abide by applicable right-of-way rules.
- When applicable, use available collision avoidance instruments and understand their associated procedures.
- If an automated detect and avoid system is used, it must give way to other air traffic in a manner that is consistent with 14 CFR §91.113.

- Monitor DAA system to maintain safe distance from other aircraft.
- Execute evasive maneuvers when required.
- When applicable, the pilot must monitor the execution of automated collision avoidance maneuvers.
- If required, override autonomous DAA system.
- Notify ATC of intentions when able.

6.19.5 Uncontrolled Flight

Proposed Minimum Operational Requirement(s)

- The pilot must be able to identify and react to equipment failures that can lead to or hinder the recovery from uncontrolled flight.
- Equipment failures must be addressed in accordance with established procedures.
- The unmanned system must make the pilot aware of conditions that may result in uncontrolled flight.
- The pilot must be aware of aircraft configurations and flight regimes in which the UA is susceptible to a loss of control.
- The pilot must be able to recognize and recover from unusual attitudes that would otherwise lead to the UA entering into a state of uncontrolled flight, when UA capabilities allow such control.
- The pilot must be able to execute appropriate spin recovery strategies for multiple types of stalls/spins, when UA capabilities allow such control.
- An emergency must be declared with ATC if control of a UA is lost.
- Standard procedures for loss of control must be published in the POH, known to the pilot, and accessible to the pilot within the control station.

Proposed Minimum Operational Procedure(s)

- Address equipment failures that can lead to or hinder the recovery from uncontrolled flight.
- Address equipment failures in accordance with established procedures.
- Interpret and react to system cues that warn of the possibility of entering into a state of uncontrolled flight.
- Avoid configurations and flight regimes in which the UA is susceptible to a loss of control.
- Recognize and recover from unusual attitudes, when UA capabilities allow such control.
- Execute appropriate stall/spin recovery strategies for multiple types of stalls/spins, when UA capabilities allow such control.
- Notify ATC of a loss of control as soon as practical.
- Know and execute any published procedures to address any loss of UA control.

6.19.6 Emergency Descent

Proposed Minimum Operational Requirement(s)

- The pilot must demonstrate the ability to execute proper division of attention in an emergency descent scenario.
- Emergency descents must be executed such that the aircraft's performance limitations are not exceeded.
- Emergency descent maneuvers must be performed with consideration given to the aircraft's configuration.
- If an emergency descent is executed, the pilot must inform ATC as soon as practical.
- The pilot will execute all descent procedures as time allows while maintaining aircraft control.
- If applicable, the pilot will brief and perform hand-off procedures to the landing pilot.
- The pilot must be able to determine whether a viable landing or termination point is within the descent path.

Proposed Minimum Operational Procedure(s)

- Execute proper division of attention in an emergency descent scenario.
- When performing an emergency decent, ensure that any performance limitations are not exceeded.
- Perform emergency descents as applicable to the aircraft's configuration (flaps, landing gear, and engine power setting) as applicable.
- Notify ATC as soon as practical when executing an emergency decent.
- Execute all descent procedures as time allows while maintaining aircraft control.
- If applicable, brief and perform hand-off procedures to the landing pilot.
- Determine if landing or flight termination is suitable.

6.20 EMERGENCY LANDING

6.20.1 Communication

Proposed Minimum Operational Requirement(s)

- Emergency landing flight plans and/or routes must be communicated with ATC as soon as practical.
- ATC must be notified as soon as possible when deviating from a clearance.
- The pilot must maintain a sterile cockpit during emergency maneuvers.
- When the situation warrants, the pilot must provide ATC with information regarding the nature of the emergency and intentions.
- During the transition portions and prior to landing, the pilot must maintain communication with ATC and any required ground crew.

Proposed Minimum Operational Procedure(s)

- Communicate emergency landing flight plans/or routes with ATC as soon as practical.
- Notify ATC as soon as practical when deviating from a clearance.

- Maintain a sterile cockpit during emergency maneuvers.
- When the situation warrants, provide ATC with information regarding the nature of the emergency and intentions.
- During the transition portions and prior to landing, maintain communication with ATC and any required ground crew.

6.20.2 Approach

Proposed Minimum Operational Requirement(s)

- The pilot must perform emergency approaches in accordance with procedures.
- The pilot must continue to monitor airspeed, altitude, and performance parameters while on approach.
- Emergency landing locations must be chosen to minimize risk to personnel and property.
- If possible, the pilot must confirm that weather minimums for landing are met.
- The pilot must ensure obstacle clearance to the best of their ability when executing an emergency landing.
- Standard procedures for emergency landings must be published in the POH, known to the pilot, and accessible to the pilot within the control station.

Proposed Minimum Operational Procedure(s)

- Perform emergency approaches in accordance with procedures for the given system.
- Monitor airspeed, altitude, and other flight performance parameters while on approach.
- Choose an emergency landing location that minimizes risk to persons or property on the ground.
- Determine effects of weather on emergency landing conditions.
- Ensure obstacle clearance to the best extent possible when executing an emergency landing.
- Adhere to any published emergency approach and landing procedures that may exist for the system.

6.20.3 Touchdown

Proposed Minimum Operational Requirement(s)

- Upon touchdown, the pilot must perform any additional emergency procedures that may be required to fully address the emergency.
- When able, the pilot must maintain communication with ATC throughout an emergency landing scenario to maintain traffic separation and clear a landing area.
- Upon touchdown, communication with any required visual observer(s) or other necessary ground support personnel must be maintained to ensure that the approach path remains clear.
- The pilot must be aware of missed approach and/or ATC requirements throughout the approach. If missed approach requirements are not established, the pilot must notify ATC.

- Standard procedures for emergency landings must be published in the POH, known to the pilot, and accessible to the pilot within the control station.

Proposed Minimum Operational Procedure(s)

- Complete any additional procedures that may be required after touching down.
- Maintain communications with ATC.
- Upon touchdown, communicate with any required visual observer(s) or other necessary ground support personnel to ensure that the approach path remains clear.
- Determine missed approach requirements.
- Complete emergency landings in accordance with any published emergency procedures for the given system.

6.20.4 Ditching (Off-site Landing) Site Selection

Proposed Minimum Operational Requirement(s)

- Aircraft ditching must be included as part of a standardized emergency checklist.
- Ditching locations must be selected based upon the ability to minimize risk to personnel and property on the ground.
- Ditching locations and pilot intentions must be communicated to ATC prior to ditching the aircraft if able.

Proposed Minimum Operational Procedure(s)

- Execute ditching maneuvers in accordance with published procedures for the given system.
- Select ditching locations based upon the ability to minimize risk to personnel and property on the ground.
- When practical, communicate ditching locations and pilot intentions to ATC.

6.20.5 Flight Termination

Proposed Minimum Operational Requirement(s)

- If the UA has the capability to flight terminate (manually or through preprogrammed control inputs), the procedures will be included as part of a standardized emergency checklist.
- At a minimum, flight termination states and parameters for execution must be known to the pilot, and the pilot must monitor the execution of flight termination, if asserted, whenever the command downlink is active.
- Flight termination locations must be selected based upon the ability to minimize risk to personnel and property on the ground.
- The pilot must communicate his/her intention to terminate the flight to ATC and provide the flight termination point.

- The flight termination procedure should engage a fuel cutoff upon activation and if able, provide an indication to the pilot when the fuel cutoff is engaged.

Proposed Minimum Operational Procedure(s)

- If required, perform flight termination.
- Execute flight termination according to established flight termination procedures for the given system.
- When executing flight termination, monitor the execution of the maneuver.
- Select flight termination locations bases upon the ability to minimize risk to personnel and property on the ground.
- Notify ATC of intent to terminate and provide the flight termination position.
- If applicable, engage the fuel cutoff upon activating flight termination.

6.21 ABNORMAL OPERATING PROCEDURES

6.21.1 General Tasks

Proposed Minimum Operational Requirement(s)

- All abnormal operational states and procedures must be included in a standardized abnormal operations checklist.
- ATC must be informed when a UA enters into a state of abnormal operation, such as abnormal gear extension/retraction, unintentional CG shift, data/communication timeouts, or non-standard performance parameters. Pilots must report any failures of instrumentation, reversion to backup or standby systems, or any other failure/abnormal operation that may impact the safety of flight.

Proposed Minimum Operational Procedure(s)

- Perform any abnormal operations procedures as they are published for the given system.
- Report any failures of instrumentation, reversion to backup or standby systems, or any other failure/abnormal operation that may impact safety of flight to ATC.

7 PC-3 VALIDATION PROCEDURE

The US Army's Universal Ground Control Station (UGCS) (Defense Industry Daily, 2013) was considered a representative device of sufficient maturity and human factors design considerations to verify operational procedures. Use of the UGCS served to validate the proposed minimum operational procedures and identified potential gaps with recommendations to the FAA. This validation procedure was not intended to evaluate the Army's UGCS for BVLOS operations in the NAS, but to validate if the recommended operational requirements and procedures were of a robust and comprehensive nature using a representative device. Details regarding the validation process results in Appendix E.

The validation of minimum operational procedures was performed on June 6, 2017 through June 8, 2017 with two Army UGCSs in Huntsville, AL using 13 flight test cards in a simulated environment. All 46-proposed minimum operational procedures were represented within the 13 flight test cards. Each of the two UGCSs were used in a simulated environment to replicate the MQ-1C Gray Eagle and RQ-7Bv2 Shadow 200 UAS respectively. Researchers noted differences between vehicle-specific modules (VSMs), using NATO Standardization Agreement (STANAG) 4586 (Platts, Cummings, and Kerr, 2007), and procedures between them, based on the capabilities of these UAS. These differences demonstrated the flexibility of a common architecture for hardware and software, which benefited this validation procedure. For example, the MQ-1C Gray Eagle operated on the airport surface area similar to manned aircraft, including taxi and ATC communications procedures; however, the RQ-7Bv2 was launched from a pneumatic launcher and did not taxi but still required ATC communications procedures. Although these differences were limitations, the variability increased researcher confidence in determining pass/fail criteria while validating these procedures.

7.1 VALIDATION APPROACH

A chronological sequence of phases of flight organized the proposed procedures into logical areas and associated to a flight test card (Appendices E and F). Validation was determined through the following types of observations:

1. Normal and abnormal procedural performance observations to validate if the proposed procedures were comprehensive and accounted for all minimum requirements needed, regardless of specific control stations used.
2. Contingency procedural observations to validate the completeness of the proposed contingency operations. In addition, to validate repeatability of proposed procedures varying contingency conditions were considered.
3. User interface observations to validate that control station controls, layout, and command and data entry sequences supported all proposed minimum procedures.

7.2 IDENTIFICATION OF PROCEDURES TO VALIDATE

Flight test cards (Appendix D) were used to document and standardize the verification observations. Multiple flight test cards were used to capture all 46 proposed procedures.

A pilot validation procedure was conducted to validate procedural accuracy in each of observation areas in controlled settings. The verification procedure was altered to improve the reliability of the data collection to ensure a more complete evaluation of proposed procedures.

7.3 FAULT REPORTING AND DATA RECORDING

Data collectors administered each flight card with a UAS operator on a UGCS control station. The data collector communicated each step in each flight card and observed the operator’s ability to perform steps using the UGCS. Results were recorded directly on each flight test card, including any specific information for a procedure’s inability to be performed or if a proposed procedure failed to adequately define the operational steps required for the safe operation of a UAS in the NAS.

Because the data collector was able to physically see the UAS Operator to know their identity, the Institutional Review Board (IRB) considered this research confidential. Each UAS Operator was assigned a UAS Operator ID number. No names or other personally identifiable information were collected. Once the test flight card data had been input into an electronic database, the original test flight cards were destroyed.

7.4 PERSONNEL RESOURCE REQUIREMENTS

Four data collectors and three UAS operators were used during the data collection. During the preliminary experiment in March 2017, requests were made to increase the quantity of UGCSs from one to two and additional UAS operators from one to three to increase the confidence of each procedure's validation using multiple iterations and collected data for each flight test performed. The data collector and UAS operator were familiar with each flight test card's procedures prior to beginning the validation of proposed procedures within each attempt. No other additional or special personnel were used or required.

UAS Operators were volunteers and had UAS system qualification and availability from the Army's UAS Project Office. According to US Army UAS Regulation 95-23 (US Army, 2006), to be considered qualified, each UAS Operator had completed either the MQ-1C Gray Eagle or RQ-7B Shadow Individual Qualification Course at the Army's UAS training institution.

7.5 EQUIPMENT RESOURCE REQUIREMENTS

The US Army uses the UGCS emulator and Universal Mission Simulator (UMS) as a Training Aids, Devices, Simulator and Simulations (TADSS) system. The device can simulate the MQ-5B Hunter, RQ7Bv2 Shadow, and MQ-1C Gray Eagle Army Unmanned Aircraft types. All of these UAS fit into the assumptions for this research. These devices provide a training capability to UAS operators for qualification training and follow-on continuation training to maintain proficiency and currency in all required operator tasks. The devices also use Multiple Unified Simulation Environment (MUSE) software to stimulate the Vehicle Control Software (VCS) for UA control, payload control, weapons control, communications, data dissemination, and mission planning.

The Army's TADSS system supports their objectives strategic vision to employ a family of UAS via common hardware and software. The Army's Unmanned Systems Integrated Roadmap (Army, 2011) identified simulation devices as a core competency for its science and technology (S&T), research, development, test, and evaluation (RTD&E) capabilities in UAS operations.

Figure 2. Universal Mission Simulator (UMS). *(U.S. Army, 2015).*

One UGCS emulator (Long, 2017) and one UGCS Universal Mission Simulator (UMS) (Ficken, 2017) were used during the validation procedure. The emulator and UMS are the same device except, the UGCS emulator reflected the same hardware and software to operate a MQ-1C Gray Eagle UAS; the UGCS UMS reflected the same hardware and software to operate the RQ-7BV2 Shadow 200 UAS (Long, 2017). The UMS replicated radio communications equipment with photographs of the equipment in their respective locations within the UGCS. System-specific Operator's Manuals and Checklists were provided and used during the data collection for each test flight card. Two fully-software-functional UGCS running simulated telemetry data provided fidelity to accurately replicate each proposed operational procedure. The use of simulation to validate operational procedures significantly mitigated the risk of loss of aircraft, equipment, or personnel while performing the flight test cards for abnormal and emergency operational procedures. No other special equipment was used or required.

7.6 <u>VALIDATION ENVIRONMENT</u>

Personnel and equipment had dedicated facilities that were free of distractions and capable of independence between UGCSs. Both UGCSs were located in Huntsville, AL at two contractor facilities approximately one mile apart. Neither UGCS had connectivity to the other. Multiple validation observations were collected by completing 13 test flight cards to observe all 46 operational procedures. A matrix for the breakdown of flight test card and operational procedure can be found in Appendix B.

7.7 <u>PERSONNEL RESPONSIBILITIES</u>

Four data collectors were required to record observations as they occurred within each test flight card. Each data collector also compared the expected results to the observed results for each operational procedure to determine an initial pass/fail status. UAS operators were responsible for performing each proposed operational procedure to the best of their ability within the constraints of any operational limitation or publication such as checklist or Operator's Manual. During the course of simulating each flight test card, the UAS Operators would manipulate the Instructor Operator Console (IOC) to induce faults or conditions necessary for the UGCS to display conditional indicators, such as warnings, cautions, alerts, or specific telemetry feedback for the UAS operator/ data collector to perform each procedure.

7.8 VALIDATION PROCEDURES

1. Each UAS Operator was presented an Informed Consent form. Each UAS operator read and signed the form.
2. Each UAS Operator sat at the UA operator workstation within the UGCS.
3. Each UAS Operator vocalized all procedures, process steps, and CS observations to ensure the data collector accurately recorded observations.
4. The data collector stood or sat either behind the UAS operator or in the sensor operator workstation, provided it is not required to perform the operational procedures outlined in each flight test card.
5. The UAS operator also performed duties as the Instructor Operator Console (IOC) administrator, interacting with the IOC to replicate each operational procedure and/or process step, as required.
6. The data collector described the operational procedure and any specific process steps required for each procedure to the UAS Operator.
7. The UAS Operator performed each operational procedure or process step by manipulating the correct subsystem controls. The UAS operator used a Graphical User Interface (GUI) and data input devices to perform the tasks. The UAS Operator also observed system responses before proceeding to the next process step or operational procedure.
8. The data collector recorded observations as the UAS Operator's performed each operational procedure or process step. Additionally, the data collection observed and recorded any operational procedure or process step that was not able to be performed.
9. Both the data collector and UAS operator proceeded through all operational procedures and process steps until each test flight card was completed.

A minimum of four observations of each of the 13 test flight cards were performed.

7.9 VALIDATION ASSESSMENT

After the completion of four observations of each of the 13 flight test cards, the research team collectively assessed pass/fail conditions for each operational by using judgement after comparing the expected-to-actual results observations recorded. The results were shown in Appendix E.

The research team recorded the collective pass/fail results from the four validation observations from each flight test card. The operational procedures within each flight test card was reviewed for agreement between all four observations. Any unanimous attempts (either a pass or fail) was accepted by the research team. Non-unanimous attempts were reviewed for any accompanying notes. With a majority rule, the data collector team determined the overall pass/fail condition from data collector comments. A majority rule of pass/fail determined the recommended operational procedure's acceptance. There were no tie-breaker validation attempts required, resulting in a majority rule decision for all 46 recommended operational procedures.

8. RECOMMENDATIONS FOR FUTURE RESEARCH

An urgent need exists to incorporate standardized organization for UAS operating documentation to capture and present procedures and performance information regarding their UAS. Some foreign states, such as Australia (2017) and Sweden (2009), began to address this issue through requirement of approved flight manuals or inclusion of flight and control station procedures in the aircraft's operation manual as a condition for access to certain airspace.

Several gaps exist among the unmanned procedures surveyed. Specific areas for future investigation and study include unmanned pre-taxi procedures, ground support operations, and rejected takeoffs. In the En-route and Landing phases of flight, gaps were found in the climb, transition, and manual (i.e. human in the loop) landing procedures. For the After Landing phase of flight, procedural gaps were noted again for ground support, parking, ground support handling, and shutdown. Among Abnormal and Emergency phases, procedures related to operations during degraded uplink, lost link (uplink), and lost link troubleshooting also appear deficient.

It is additionally recommended for research in the following areas:

1. Validate recommended procedures during an actual flight environment.
2. Validation of procedures using a HF-optimized prototype CS.
3. Development of a PTS/ACS – performance based standards – with the minimum procedures for CS recommended from this research.
4. Research high and low traffic conditions relating to minimum tasks required.
5. Research runway independence vs runway dependence between UAS platforms and differences in requirements – for example – a runway-independent UAS may have different weather infrastructure requirements. Also, how are procedures different – having to taxi on a runway versus no taxi necessary.

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APPENDIX A—COMPARISONS BY PHASE OF FLIGHT

Appendix A provides information about the similarities and differences in requirements, practices, and procedures between UAS and unmanned to manned aircraft were divided by phases of flight that was determined in research task PC-1. The phases of flight are presented in the temporal order of flight progression from prior to take-off through engine shutdown upon landing. Some phases of flight were further broken down into categories given specific requirements or importance those sub-categories play during that particular phase. Additionally, researchers included abnormal or emergency procedures after the normal phases of flight, addressing not every possible emergency, but those which standards or checklists are most often included across all aircraft due to the significant nature and potential outcome.

A. PREFLIGHT

1. Before Entering GCS – [Preflight]

a. Common practices among UAS

Common practices between UAS included the need to obtain weather observations and forecasts, crew health analysis or CRM check, NOTAMS, or a review of instrument procedures. Many systems required obtaining information necessary for navigation performance infrastructure along the planned route, the availability of an instrument approach at the destination; alternate landing sites, fuel requirements and alternate airport fuel requirements. Other commonalities included a confirmation of the quality and availability of C2 links and filing a flight plan when required.

Fuel planning was consistent across UAS to ensure the aircraft is carrying enough usable fuel on each flight, although there was a variation of the amount of reserve fuel based on a percentage of planned flight time or a minimum reserve time in minutes. Same considerations on endurance and flight duration is also made with regard to electric powered aircraft with consideration to battery life.

b. **Common practices among UAS and manned aircraft**

Require the pilot to become familiar with all available information concerning each flight. Additionally, required proficiency areas include checklist usage, ability to properly identify aircraft discrepancies, procedures for deferring inoperative equipment, proper fuel and oil servicing.

For instrument flight, planning was required for the identification of forecast weather, alternate airports, and fuel requirements. The length and configuration of the runway (i.e. grade, crown, and slope) were also planning considerations.

c. Unique differences between UAS or UAS to manned systems

Variation between UAS existed. Some requirements of manned aircraft relating to the crew manifest, people on board the aircraft, oxygen, etc. were not required for UAS. Some UAS and manned aircraft systems required the physical inspection of the aircraft, ground control, and ground support equipment prior to entering the control station. Some UAS required a physical inspection of the ground control and support equipment prior to entering the control station. Variances were noted in the requirement to complete the physical inspection of the aircraft. Some were after the preflight inspection was complete, but before the engine start procedures, others were a part of or before the preflight.

Note: UAS reviewed included systems that performed horizontal takeoff using traditional runway environments. Some UAS used catapult launcher devices and were runway independent for takeoff.

2. Before Engine Start – [Preflight]

a. **Common practices among UAS**

Common practices verify the functionality of the aircraft and control station through a methodological process. The methods used by each system are unique to that system. Minimally, the functionality of the avionics, sensors, actuators, lighting, flight control surfaces, servo actuators, data links, fuel and oil levels are checked. Levels of autonomy for the UAS are verified from creating, saving, and uploading mission and emergency mission plans, loading the plans to the aircraft, and verifying the plan was received. Some systems require the activation of the mission plan during the preflight to observe control station indicators reported from the aircraft and physical changes to the aircraft such as deflection/ orientation of deflection of flight control surfaces or throttle position prior to engine start.

Many UAS platforms rely on communication between the ground station and the crew out at the aircraft as well as the hand-off ground station when applicable. There were procedures noted where extensive radio checks were made, to include phone checks, prior to engine start.

b. **Common practices among UAS and manned aircraft**

Manned aircraft procedures also required an aircraft inspection to detect possible defects within the aircraft including documentation such as airworthiness, registration, currency of electronic data, identification of minimum equipment required for flight, avionics; engine controls, lighting, electrical fuses, circuit breakers, and annunciators, flight control surfaces, landing gear wheels and tires.

UAS aircraft mimicked manned aircraft by requesting engine start, as a requirement when at a controlled airfield, and putting clearance on request when applicable.

c. Unique differences between UAS or UAS to manned systems

There were some limitations to the data collected for this task because many procedures require the use of a system-specific checklists to perform this portion of the preflight. Many checklists contained either proprietary information or were ITAR controlled, limiting their use in this research.

Many of the manned aircraft requirements were not applicable to UAS. For example, seatbelts were required to be inspection and passengers were required to be instructed in their use. Additionally, fire extinguishing equipment and life support equipment were required to be inspected during a preflight inspection. Currently, these requirements are not applicable to UAS because there are no people on board the aircraft; however, if UAS begin to perform people transport operations, then requirements such as these may be required.

A preflight inspection for a UAS may require other crewmembers to perform checklist such as a crew chief or sensor operator. Establishing and maintaining communications with other crewmembers during the preflight inspection varied between UAS as well as manned systems.

Manned aircraft before-engine-start procedures had requirements, not clearly identified in most commercial UAS platforms such as procedures and required documentation, flying with inoperative equipment, limitations of flying with inoperative equipment, requirements for having a current aviation database, equipment required for IFR flight, IFR airworthiness to include aircraft inspection requirements. It was only noted in military UAS platforms were the above listed requirements were present.

There were additional ground stations requirements present in UAS that were not similar to manned aircraft. The large amount of computer equipment in a ground station produces a lot of heat. There were steps to verify the ground station was under a certain temperature to ensure the computers would not overheat. There were also steps to confirm the ground station was configured in flight mode as some of these stations also have the capability to duplicate as simulators.

3. Engine Start – [Preflight]

a. Common practices between UAS

Common practices for performing the engine start task use UAS-specific checklist procedures. Most UAS required the proper positioning of aircraft, including mooring the aircraft to prevent movement. The engine start procedure for many UAS required other crewmembers to perform such as a crew chief or maintainer.

Establishing and maintaining communications with other crewmembers during the engine start procedure varied between UAS. All UAS required the pilot to monitor engine-related information, such as RPM, fuel flow, oil pressure, and bus voltage output to determine if the engine was operating within normal operational parameters. Some UAS platforms required the pilot to verify throttle position prior to engine start and change the throttle position during an engine run while verifying normal operating parameters at other-than-idle RPM.

Additionally, the majority of the surveyed UAS platforms had a procedure during emergencies, to quickly shut the engine off.

b. **Common practices between UAS and manned aircraft**

Commonalities between UAS and manned systems included the proper positioning of the aircraft to ensure propeller safety. Engine starting procedures also required the ability to monitor the electrical system and RPM during the starting procedure. Adherence to checklist procedures were also required.

It was noted on a few UAS platforms considerations for cold and hot weather procedures that were similar to manned aircraft.

Requirement for a fire bottle was also duplicated for larger-than-small UAS on a controlled airfield during engine start.

c. **Unique differences between UAS or UAS to manned systems**

Some UAS's had the capability to start the engine without the need for support equipment. Some UAS required support equipment such as an air start cart or a computer plug-in to monitor indications until a link could be established.

Researchers were unable to determine the specific engine start procedures from the UAS-specific documentation provided. Manned aircraft engine starting procedures included details for failures or emergency procedures during or after engine starting procedures. The manned aircraft procedures included propeller safety information for passengers, which currently is not required for UAS because it is assumed that no passengers would be on board the UAS.

The manned aircraft engine starting procedures also provided details for abnormal starting procedures, hand propping to start the engine, high altitude operations, and hot or cold weather environments. The manned aircraft engine starting procedures also included emergency starting information that wasn't as well documented or existing in other UAS platforms.

4. Pre-Taxi – [Preflight]

a. Common practices between UAS

A visual observer to clear taxi path and follow through taxi was a requirement for some of the UAS platforms in our research. A confirmation that all personnel and equipment were cleared prior to requesting clearance was a procedure noted.

b. **Common practices between UAS and manned aircraft**

Pilots, both manned and UAS, showed requirements to get current ATIS, altimeter setting and finish all pre-taxi checklists prior to asking for taxi.

Information from UAS and manned aircraft operations focused on knowledge and awareness prior to beginning the taxi operation. Knowledge included procedures for appropriate cockpit activities during taxiing including taxi route planning, communications with ATC, understanding procedures for steering, maneuvering, maintaining taxiway, runway position, and maintaining awareness, understanding relevance/importance of hold lines, and understanding taxi operation planning procedures.

c. Unique differences between UAS or UAS to manned systems

Considerations for icing (such as anti-icing or de-icing) prior to taxi was observed within the manned aircraft pre-taxi operations; however only some UAS researched had de-icing capabilities.

Understanding taxi operations for procedures unique to night operations, non-towered airports, and aircraft lighting; understanding the hazards of low visibility taxi operations was not identified in UAS operations as it is in manned.

Manned aircraft documentation also provided information about the proper settings of the different avionics systems and flight instruments.

A brief between the safety observer and the UAS operator is made prior to taxi to ensure proper verbiage is used and any other pertinent information to be past.

B. TAXI

1. Communication and Pre-Takeoff Checks

a. Common practices between UAS

Common practices included the ability to communicate and comply with ATC instructions. All UAS reviewed used runway markings during taxi operations. UAS were required to taxi at safe speeds; only one system provided maximum taxi speeds.

b. **Common practices between UAS and manned aircraft**
Common elements for taxi operations between UAS and manned aircraft include the compulsory requirements to comply with ATC instructions and procedures (e-CFR, 2017).

Brake checks were required an all aircraft that taxied from a parking location to the runway.

Taxi speeds and safe taxi distances were also a requirement on most aircraft researched.

c. Unique differences between UAS or UAS to manned systems
Some UAS require no taxi whatsoever. These UAS are catapult launched instead of taxied from a storage location such as a hangar to the launch and recovery site on the airport may occur prior to preflight. These aircraft are towed by another vehicle, which should use ATC instructions to the driver of the vehicle to comply with ATC instructions as if the aircraft was taxing under its own power.

Some UAS required the use of an External Operator and marshalling personnel or the vehicle operator to visually clear the aircraft while taxing on the airport surface. The external Operator maintained a visual contact with the aircraft and radio communications with the marshalling team and tower during taxi operations.

Manned aircraft taxi procedures included the sustainment of a sterile cockpit and monitoring of flight instruments during taxi operations.

C. TAKEOFF

1. Communications – [Takeoff]

a. Common practices between UAS
Commonalities in takeoff communication procedures fell along the lines of highlighting the necessity to communicate with ATC prior to takeoff. These procedures, while highlighted at a fairly high level, pointed to the need to ensure clear communication with ATC using standard aviation terminology and phraseology.

Procedures also emphasized the need for clear communication amongst the crew, both in the ground station or through use of a radio for dual shelters and/or visual observer operations.

b. Common practices between UAS and manned aircraft
Commonalities were rooted in the requirements to clearly communicate with ATC, and communicate with essential crew. In the context of takeoff, communications with ground

crew, such as those responsible for marshaling the aircraft, and ATC are expected to adhere to existing standards, using typical aviation phraseology and terminology.

c. Unique differences between UAS or UAS to manned systems

With all common communication procedures being very similar, the biggest difference that was noted was the requirement to acknowledge ATC light signals. There is an obvious limitation of a UAS to not be able to acknowledge light gun signals due a potential inability of the UAS pilot to visually acquire light gun signals.

Note: It should be noted that documentation for some small unmanned aircraft system (sUAS) were reviewed. While these systems were generally considered to be out of scope for this research project, it was included for the sake of comparison. It highlights key operational differences and presents a case for differentiating procedures that are intended for small unmanned aircraft systems (sUAS) and larger, more complex systems. Especially in the communications and takeoff phase for comparisons.

2. Takeoff – [Takeoff]

a. Common practices between UAS

Similar requirements for a takeoff run revolve around establishing the aircraft is ready for takeoff (verifying completion of pre-takeoff checks), performing the takeoff itself, and monitoring aircraft status and function after takeoff. These procedures primarily consisted of ensuring that the aircraft was aligned and positioned on the correct runway, applying power/commanding a takeoff, ensuring rotation at the correct airspeed, and establishing a steady climb.

An emphasis on monitoring of aircraft systems and functions was also common, requiring the pilot to check flap settings prior to takeoff, rotation at the desired airspeed, status of the navigation system, and the correction function of the aircraft throughout takeoff.

Monitoring of systems continues through takeoff and into climb out, with the pilot continuously monitoring system status and verifying that such things as flap retraction, navigation, and any required automation are functioning correctly. Should any anomalies occur that necessitate a rejected takeoff, it is initiated per the required procedures.

b. Common practices between UAS and manned aircraft

Common procedures between manned and unmanned aircraft at takeoff included many of the same fundamental requirements for fixed-wing takeoff. The UAS, like a manned aircraft, required the aircraft to be positioned on the correct runway relative to wind direction, verification of ATC clearance, and that the takeoff run be initiated with the aircraft when all required variables such as traffic and aircraft system status are accounted for and known to the pilot.

c. **Unique differences between UAS or UAS to manned systems**

One of the more obvious differences between manned and unmanned takeoff procedures is that not all unmanned aircraft are capable of performing a conventional takeoff. While other platforms were capable of performing either a conventional takeoff or a catapult launch, depending upon the mission requirements. The ability to utilize less conventional takeoff methods, such as a catapult creates drastically different procedures and requirements for takeoff than those for conventional manned aircraft. This is especially true given that aircraft that have a simple "push button" launch system that initiates a takeoff with a high degree of autonomy, requiring little (if any) pilot intervention upon launch.

Some UAS platforms had an autonomous abort built into the system. Others had red warning lights and/or accompanying aural tones to indicate an abnormal indication to help a pilot facilitate a timely abort if needed.

Research only discovered standards and procedures in military UAS's that referenced bird conditions and requirements associated with those conditions in relation to take-off and landing. Bird hazards and conditions were addressed throughout manned aviation.

3. Ground Support – [Takeoff]

a. **Common practices between UAS**

A Requirement for ground support at takeoff varied by systems and was not fully captured in available documentation. While there are requirements to utilize supporting ground crew and/or equipment for several unmanned aircraft systems addressed by the literature, few specific procedures matched when compared between systems. Additionally, there were some platforms that relied on maintenance or communication troops to facilitate or participate in checklists. Those documents were not made available to researchers.

b. **Common practices between UAS and manned aircraft**

No common ground support requirements were identified between manned and unmanned aircraft except the need to have a fire bottle during engine start. The need for dedicated ground personnel to marshal a manned aircraft and provide a means to clear a runway of traffic is diminished for a manned aircraft due to the presence of a pilot onboard the manned aircraft.

c. **Unique differences between UAS or UAS to manned systems**

For manned aircraft, the requirement for support equipment and ground support personnel often ends upon the start of taxi. This being the case, there was very little commonality between manned and unmanned aircraft in terms of ground support for takeoff. For unmanned aircraft, the requirement for ground personnel extends up to the completion of takeoff. Taxiing and visually clearing taxiways, runways, and parking locations is automatic for a manned aircraft due to the presence of a pilot in the cockpit. With unmanned aircraft,

these simple tasks become more complex when the pilot is removed from the aircraft and high levels of autonomy are exercised. The addition of ground personnel to perform these visual checks becomes a necessity unless a different means to visually clear the taxiways, runways, verify configuration, and externally monitor the climb are available to the pilot.

These functions are not dissimilar to the role of visual observers in the context of many sUAS operations—a dedicated person on the ground to provide deconfliction of the UA from objects…in this case, on the ground.

4. Aborted/Rejected – [Takeoff]

a. Common practices between UAS

Little information was available for the comparison of rejected takeoff procedures. A few of the platforms had abort procedures related to aircraft being outside limitations while on takeoff roll or due to malfunction of critical equipment.

Upon examining the rejected (aborted) takeoff procedures there are some basic elements that are immediately noticeable, and are applicable to all manners of UAS. When the procedure is broken down to the fundamental level, it requires the pilot to perform several basic tasks to ensure a safe abort. The basic tasks/requirements for an aborted takeoff are:

a. The pilot must first recognize the need to reject the takeoff,
b. Control of the UAS must be maintained by the pilot at all times,
c. The pilot must bring the aircraft to a stop as quickly and safely as possible, and
d. If the aircraft departed the runway, the pilot must shutdown the engine immediately.

b. Common practices between UAS and manned aircraft

Very little information was available to make this comparison. Limitations in the types of documentation available prevented a full comparison here. A commonality shared was to notify ATC of the abort as soon as aircraft control could be maintained.

c. Unique differences between UAS or UAS to manned systems

Little information on abort procedures was available to the research team. This is due to the differing sources of information and the proprietary/restricted nature of many of the systems that were considered for this research. The lack of listed procedures here points to limitations on the kinds of information that the research team was able to obtain and/or release.

One difference identified, which may be unique to unmanned aircraft, pertained to some of the autonomous behaviors of some systems. Some aircraft, under certain criteria like a lost link would abort automatically. Also, some aircraft would reject the abort input after certain airspeed, such as V1 was reached. In such cases, the aircraft would continue to takeoff.

D. CLIMB-OUT

1. Climb-Out - [Climb-Out]

a. Common practices between UAS

Climb out procedures and requirements varied between different unmanned aircraft, and were often embedded within takeoff procedures. However, commonalities observed between unmanned aircraft revolved around system monitoring and ensuring the aircraft and associated systems perform within their desired constraints.

At the most basic level, common elements of UAS climb performance related to the necessity of the pilot to understand climb characteristics of the UAS and how they may be affected by pilot inputs. At the deeper level, these procedures consist of ensuring that such things as rotation at the desired airspeed, the raising of landing gear and flaps, the proper climb attitude and airspeed is achieved, engine function is normal for the climb power setting, ATC communications are maintained, directional control is maintained, and systems are monitored for any abnormal operation.

b. Common practices between UAS and manned aircraft

Common areas between manned and unmanned climb out procedures were largely focused on the tasks performed during climb out. These tasks primarily consisted of such things as ensuring that the aircraft was rotated at the correct speed to initiate a climb, the gear were raised and flaps retracted, critical systems were monitored, and the correct pitch and airspeed required for the climb were maintained until reaching the desired altitude.

Communications on climb-out were mirrored. Tower switching over to departure and requirement to check-in with departure, was duplicated with the same verbiage and intent.

c. Unique differences between UAS or UAS to manned systems

Despite their similarities, there are some distinct differences between manned and unmanned aircraft when addressing aircraft climb procedures. Levels of automation within unmanned aircraft can vary, ranging from nearly full automation to manual pilot control. While the tasks that were performed between both manned and UAS were largely the same, the manner in which they were performed differed. Systems with high levels of automation perform many of the critical post-takeoff climb functions such as raising the gear and flaps with a high degree of autonomy. Some platforms are capable of initiating an automated takeoff and subsequent climb with a button press. This places the pilot in the role of monitoring system function, rather than actively piloting the aircraft.

Additionally, the automation of some UAS platforms regulate the rate of climb so the pilot is unable to shallow or increase feet per minute of the climb. The rate at which it climbs and descends will remain constant and can only be changed through level off.

Manned aircraft climb out procedures provided a greater emphasis on obstacle avoidance. While it is certain that this is an important factor in unmanned aircraft climb out procedures as well, it was not a prevalent in the sources that were compiled. This likely a result of the limitations of documentation available for this research.

E. EN-ROUTE OPERATIONS

1. Communications – [En-route]

a. Common practices between UAS

UAS systems that have the capability for launch and recovery in one geographical location, and the ability to execute command and control for the en-route portion of the flight from a separate geographical location have unique communication requirements. This type of operation is often referred to as "remote split operations" and is common for UAS that fly beyond line of sight (BLOS). The communication between the Launch and Recovery Element (LRE) and the Mission Control Element (MCE) is essential for smooth transition of aircraft control and to keep updated on any changes in expected times for the scheduled or non-scheduled transition to occur.

For UAS that do not fly BLOS operator and observer should remain co-located and communicate verbally.

b. Common practices between UAS and manned aircraft

UAS and manned aircraft both require an operator to exhibits the knowledge, and skills to communicate with Air Traffic Control (ATC) for clearances and procedures within the National Airspace System (NAS). The skill to use and understand the proper phraseology and to correctly copy, read back, interpret, and comply with an ATC clearance is common between platforms.

Knowledge and skills are required to correctly set up communication frequencies, navigation systems and transponder codes in compliance with the ATC clearance along with monitoring proper frequencies, including emergency frequencies.

c. Unique differences between UAS or UAS to manned systems

Manned aviation systems do not have a condition similar to the unmanned aircraft systems remote split operations. This set of required skill and knowledge is new for those operators transitioning from manned to UAS

UAS aircraft that operate BLOS rely heavily on a control structure of satellites and other communication links. The monitoring of these control links is crucial and the ability to switch between them, if the capability allows so, when one becomes degraded or no longer useful is unique to UAS.

2. Navigation (including GPS availability) – [En-route]

a. Common en-route navigation requirements between UAS

Due to the large variation of UAS, the common en-route navigation requirements are also dramatically different between different UAS. However, based on the purpose of navigation there were a few commonalities found. Pilot is expected to navigate the unmanned aircraft in reference to latitude, longitude, altitude, speed, and time and demonstrate the ability to use all installed navigation systems (if any navigation systems are installed). There was a strong reliance on visual navigation and/or GPS navigation across the platforms. Pilot skills also included being able to locate the unmanned aircraft's position using visual contact and/or the navigation system, exhibit satisfactory knowledge to keep the unmanned aircraft inside its authorized airspace (latitude, longitude, altitude, speed, and time), and consistently monitor present position with lost link failure route to ensure route will not violate airspace or be unable to maintain obstacle clearance. All pilots of UAS platforms were expected to exhibit satisfactory knowledge of airspace restricted from UAS use.

b. Common practices between UAS and manned aircraft

Due to the large variation of UAS and manned aircraft, the common en-route navigation requirements are also dramatically different between UAS and manned aircraft. The need for a complex navigation system increases as an aircraft integrates into controlled airspace. The redundancy or back-up navigation systems vary from platform to platform.

A common characteristic with manned and unmanned aircraft is the use of automation to ensure adherence to navigation requirements. Small aircraft, flying in uncontrolled airspace typically utilize the pilot to navigate their aircraft. As the unmanned and manned aircraft become more complex, the use of automation will guarantee proper navigation.

Common navigation requirements between manned and unmanned aircraft included utilizing the same GPS constellation for navigation, navigate in reference to latitude, longitude, altitude, speed, and time, and locate the airplane's position using the navigation system. Additional skills expected were intercept and track a given course, radial, or bearing, as appropriate, verify route does not violate airspace and avoids obstacles, and recognize navigation signal loss and take appropriate action. When using the GPS for navigation, pilots also should possess knowledge of Global Positioning System (GPS) or Global Navigation Satellite System (GNSS) (equipment, regulations, databases authorized use, Receiver Autonomous Integrity Monitoring (RAIM).

c. Unique differences between UAS or UAS to manned systems

It is not surprising to find large variations between UASs and manned systems concerning en-route navigation requirements. Some UAS platforms utilize a high degree of automation, some have no automation, and some utilize a hybrid between the two levels of automation. The use of automation affects how the aircraft navigates, and who is responsible for safely navigating the aircraft. Additionally, some UASs are fully autonomous, some are not autonomous, and some UASs utilize a hybrid of non-autonomous and fully autonomous operations. If a UAS has no automation, the pilot will navigate the aircraft. As a system becomes more automated, the pilot will manage the automation. The following two examples of automated and manual conditions point out the different roles of the pilot in order to execute the UAS mission.

1. AUTOMATED - CONDITIONS: 1). Set proper flight mode for cruise flight. 2). Verify the aircraft enters the selected flight mode. 3). Verify cruise airspeed, heading, and altitude are set to programmed settings.

2. MANUAL CONDITIONS: 1). Change heading commands to meet mission waypoints. 2). Adjust for winds. 3). Adjust airspeed commands to meet time on target (TOT) requirements while staying within the operating parameters. 4). Adjust altitude commands to meet waypoint requirements or air traffic control (ATC) directions. 5). Ensure aircraft maintains airspeed and altitude within assigned parameters of the aircraft operating limits.

The size of the aircraft will also affect its navigation capabilities. Some large transport aircraft carry multiple GPS units and other navigation aids. A prudent pilot will always use all available navigation sources during en-route navigation. The number of available navigation sources is widely varied from aircraft to aircraft.

Unique navigation requirement differences between UAS to manned systems were small UASs often use GPS to determine altitude, but most manned aircraft utilize pitot static instruments, UASs monitor present position with lost link failure route to ensure route will not violate airspace or be unable to maintain obstacle clearance and if a manned aircraft loses ground communication, it typically continues on its preplanned route of flight. Also, small UASs have the ability to immediately terminate flight when navigation capabilities are lost, where a manned aircraft needs to reestablish its location and navigate to a landing area.

Another difference is most manned aircraft use vertical navigation to avoid other aircraft, however many UASs are too low to the ground to use altitude confliction methods. Additionally, a manned aircraft pilot often uses see and avoid in order to avoid a midair collision. A UAS pilot often uses sense and avoid in order to avoid a midair collision.

3. **Climb – [En-route]**

   a. **Common practices between UAS**
   Information regarding requirements for UAS for this task in the en-route phase of flight was scarce. The majority of unmanned platforms reviewed do not appear to have formalized procedures or standards for accomplishing an en-route climb. Of the unmanned platforms, a group II fixed wing platform described the need for the PIC to "understand the climb characteristics of the aircraft" as well as the "climb rate controlled by the autopilot" and how this is adjusted manually and by the aircraft's automation during waypoint navigation.

   b. **Common practices between UAS and manned**
   Both unmanned and manned systems seemed to lack formalized procedures for this task. While the reason for this absence is unclear, the PIC of either platform must understand the climb characteristics of the aircraft and how this performance can be adjusted.

   For instrument flight, both unmanned and manned aircraft will be required to perform at least to the minimum climb performance used in determining Minimum Crossing Altitudes (MCA) for en-route instrument flight (i.e. 150 Feet Per Nautical Mile below 5,000', 120 ft/NM below 10,000', and 100 ft/NM above 10,000' MSL) (FAA Order 8260.3B).

   c. **Unique differences between UAS or UAS to manned systems**
   Although few UAS provided standards or procedures for performing an en-route climb, variation between navigation systems and level of automation are likely to be differentiators both among unmanned platforms as well as between unmanned and manned aircraft.

   The level of automation is some UAS's did not allow the pilot to increase or decrease climb rate as the computer determined best rate of climb and used that information to regulate airspeed, angle of attack and other flight controls to optimize the climb.

4. **Descent – [En-route]**

   a. **Common practices between UAS**
   Requirements reviewed for UAS indicated a focus on the ability of the PIC to anticipate the airspeed, altitude, and heading of future waypoints and to plan their descent accordingly while monitoring system health (e.g. pitch indications, proper airspeed and altitude responses, vertical speed and engine indicators).

Regardless the level of autonomy assisting in the descent, a second theme was found in a need for the PIC to again understand the performance envelope of their aircraft and to plan their descents accordingly.

b. Common practices between UAS and manned aircraft

Both unmanned and manned systems standards and procedures call for the PIC to understand and operate within the performance envelope of their aircraft. The need to plan descents with future waypoints or procedures in mind while monitoring system health is also universal.

c. Unique differences between UAS or UAS to manned systems

A notable distinction between unmanned and manned systems was presented in this task within descent planning with regards to the waypoint navigation system utilized by some UAS. Specifically, the procedures for a group II fixed wing UA describes a need to "Establish waypoints … to integrate [the] approach with manned aircraft procedures." Although waypoint navigation appears common among UAS, these navigation systems lack standardization and do not appear innately compatible with existing NAS procedures.

5. Cruise Power Settings – [En-route]

a. Common practices between UAS

UAS systems reflect highly automated systems, based on terminology in literature. The terminology is predominately managing airspeed and altitude, statements such as "do not exceed system limitations", "monitor fuel level", "set flight mode" are used, but little guidance in regard to actually setting cruise power settings is stated. One widely used platform requires, "an in-flight fuel consumption check 30 to 60 minutes after level-off or entry into cruise flight. Initiate alternate course of action if actual fuel consumption varies from the planning value, and the flight cannot be completed with the required reserve. Monitor fuel quantity and consumption rate during the flight." This also refers to performance automation that is monitored by the operator. Another platform states, "The Operator shall continuously monitor battery voltage".

b. Common practices between UAS and manned aircraft

Both UAS and manned require an applicant to exhibits satisfactory knowledge, risk management, and skills associated with ensuring the aircraft is performing as specified.

Altitude and airspeed, whether controlled by automation or power settings on a manned aircraft, require input by the operator and continued monitoring to ensure the expected results are maintained. Most manned and unmanned aircraft have multifunction display to monitor fuel burn rate, current fuel levels, system parameters are met as well as warnings and cautions should the system not operate properly. Manned aircraft verbiage is much more manual than the automation terminology used within the UAS, but both require regular monitoring of the system.

c. Unique requirements differences between UAS or UAS to manned systems

Manned aircraft verbiage is much more manual than the automation terminology used within the UAS. Procedures are more mature but involve more manual input of power settings and fuel control, such as mixture to obtain optimal performance. UAS systems are more automated, in which performance in maximized through automation instead of operator input. It becomes a monitor the indications verse provide input to get desired indications.

Fixed wing aircraft generally refer in terms of fuel burn and use of traditional power source such as AvGas. While larger-than-small unmanned aircraft are not as likely to be electrically powered – they may be powered by means other than traditional fuel, for example the Altavian states, "The Operator shall continuously monitor battery voltage". When considering cruise power settings, this may be significant to an unmanned aircraft but would not be a significant consideration for manned aircraft.

F. LANDING

1. Communications – [Landing]

a. Common practices between UAS

In general, there were no common practices across all platforms besides the requirement to coordinate descent and landing with ATC. Two platforms referred to communication with operating control towers in preparation for landing.

b. Common practices between UAS and manned aircraft

For the UAS platforms that discussed landing communication they aligned with the manned standards in 14 CFR 91.129(i) "Takeoff, landing, taxi clearance. No person may, at any airport with an operating control tower, operate an aircraft on a runway or taxiway, or take off or land an aircraft, unless an appropriate clearance is received from ATC."

c. Unique differences between UAS or UAS to manned systems

The unique difference between systems is that some systems did not address the topic or those that did only stated that crews should maintain communication and seek clearance prior to landing procedures. This is stated clearly in manned aircraft due to the requirements of 14 CFR.

Due to the previous requirements to be a rated pilot for operation of UAS, coupled with the restrictions of operating in controlled airspace, the procedure to communicate with Air Traffic control may be sparse because they are the standard operating procedures trained for manned operations and may be assumed. Additionally, for hand and catapult launched systems they do not operate in manned airspace and therefore there is normally no requirement to contact prior to take-off and landing operations.

2. **Transition – [Landing]**

   a. **Common practices between UAS**
   There were no Common practices between UAS. On the unique platforms which had split operations, the time to do hand-off between shelters varied. Once the aircraft was within Line of Sight (LOS) links, usually was the time the shelters would switch from mission control to launch/landing control.

   b. **Common practices between UAS and manned aircraft**
   Due to the lack of procedures for transition in both manned and unmanned no commonalities and dissimilar actions can be highlighted.

   c. **Unique differences between UAS or UAS to manned systems**
   Due to the lack of procedures for transition in both manned and unmanned no commonalities and dissimilar actions can be highlighted with the exception of split operations hand-off mentioned previously.

3. **Approach – [Landing]**

   a. **Common practices between UAS**
   For systems that included Approach procedures the requirements were in general common between all platforms. Each procedure in some wording included verify fuel / flight time in case of a go-around, approaches and go-around options via chart or mission planning tools, and review and establish descent rates, weather, obstacles, etc. prior to commencing the approach.

   b. **Common practices between UAS and manned aircraft**
   Common between UAS and manned is the UAS uses the spirit of the manned procedures for approach to include checklists, communication with ATC and required briefings with crew.

   c. **Unique differences between UAS or UAS to manned systems**
   The unmanned procedures in some cases reference mission planning tools whereas manned procedures do not use a mission planner or GCS.

   Additionally, some UAS platforms required the visual observer to be present for the landing to verify configuration, correct landing runway and expedite taxi off. It would be during the approach phase the pilot would verify observer has two-way communication with the pilot and is in position for the landing.

4. Landing (Non-Automated) Approach and Landing – [Landing]

a. Common practices between UAS

There were no specific procedures for non-automated landings within the scope of this research.

b. Common practices between UAS and manned aircraft

The landing phase was considered a critical phase of flight and therefore the only commonality that could be drawn was for there to be a sterile cockpit during this phase.

Confirming landing gear was down and clearance was given to land was a commonality shared between manned and unmanned platforms.

c. Unique differences between UAS or UAS to manned systems

For manned aircraft, 14 CFR has very detailed guidance on both VFR and IFR landings. For UAS the information was not abundant enough to draw any conclusions from.

5. Landing (Automated) Approach and Landing – [Landing]

a. Common practices between UAS

For aircraft that included landing procedures, the procedures were similar in that the aircraft and operator were configured for the landing phase, reviewed the pilot checklist, communicated and verified that the ground crews were ready, and then initiated the landing.

b. Common practices between UAS and manned aircraft

The information for this phase of flight was not abundant enough to draw any conclusions from.

c. Unique differences between UAS or UAS to manned systems

The main difference is that manned aircraft traditionally do not land using automated systems. For those that do the procedures were similar in that the aircraft were configured, checklist complete, and landing initiated.

For UAS aircraft that relied on a visual observer, a final confirmation of aircraft configuration, alignment to runway, and runway approach path, runway was clear of all aircraft and equipment was procedural.

6. Go Around – [Landing]

a. Common practices between UAS

There were numerous Common practices between UAS systems in regards to missed approaches and go-arounds. Each procedure that was included followed similar procedures of determining risk and initiate a missed approach procedure. Pilots were to communicate intent, apply power, climb to a safe altitude (various procedures stated different altitudes), and reposition to begin approach or transition to alternate landing area.

b. Common practices between UAS and manned aircraft

The missed approach procedures for manned and UAS were common between them both in stating intentions to ATC and executing the go around with a smooth climb at runway heading to a safe altitude.

c. Unique differences between UAS or UAS to manned systems

The noticeable differences were the platform specific details. Depending on the platform the level of detail was different on climb out, attitude, etc.

The technology built into some UAS platforms sends the aircraft into a go-around autonomously if it breaks from one of its landing parameters. Also, the pilot can select the go-around manually, but on these same platforms the aircraft performs the go-around autonomously once selected.

Some UAS platforms have a minimum altitude in which a go-around can be selected due to the lag time between entering a command and the aircraft receiving the command. Once the aircraft is below the minimum altitude established, the aircraft will ignore the pilots command and continue to land.

7. Ground Support – [Landing]

a. Common practices between UAS

There was little written about ground support for UAS. Those platforms that included the information referenced communicating with the ground crew to ensure that they are ready for recovery and support.

b. Common practices between UAS and manned aircraft

There were no commonalities discovered during this research.

c. Unique differences between UAS or UAS to manned systems

The unique differences are in manned operations there is limited discussion of ground support after landing. Even though there are few UAS platforms that discuss ground support, the ones that do require it, provide ample guidance.

G. POST LANDING

1. **Communications – [Post Landing]**

   a. **Common practices between UAS**
   In general, there were two requirements noted in the procedures that included post landing communication; communicate with ground crew and communicate with ATC.

   b. **Common practices between UAS and manned aircraft**
   The commonalities are that in both manned and UAS that communication between the pilot, crew, and ATC are critical.

   c. **Unique differences between UAS or UAS to manned systems**
   The unique differences are that the manned procedures provide more detail about when and what to communicate. 14 CFR 91.129(i) states; "Takeoff, landing, taxi clearance. No person may, at any airport with an operating control tower, operate an aircraft on a runway or taxiway, or take off or land an aircraft, unless an appropriate clearance is received from ATC."

2. **Ground Support – [Post Landing]**

   a. **Common practices between UAS**
   Across each aircraft that listed procedures there were Common practices that include verifying the aircraft is in a safe location, securing the aircraft, and conducting shutdown checklists and post flight. Finally, the ground crew was to communicate the shutdown had been completed to the pilot.

   b. **Common practices between UAS and manned aircraft**
   In manned flight, there are ground support and shutdown procedures conducted by the pilot and crew. The procedures between and manned and UAS were similar in nature.

   c. **Unique differences between UAS or UAS to manned systems**
   The unique difference is the pilot is not in the vicinity of the aircraft and ground crew. Therefore, the communication is done remotely which imposes additional communication requirements and procedures.

3. **Taxi – [Post Landing]**

   a. **Common practices between UAS**
   The common requirement shared is if an aircraft has the ability to taxi, then clearances must be approved prior to moving the aircraft.

   b. **Common practices between UAS and manned aircraft**
   The taxi procedures between manned and UAS are very similar in that they both follow the 14 CFR and require clearance for taxi operations.

c. **Unique differences between UAS or UAS to manned systems**
The main difference is in the UAS the pilot does not have as much information of obstacles on the ground as a manned pilot. The UAS pilot is remote and relies upon the ground support in many instances to direct and observe for the pilot therefore this adds a risk to any taxi operation a manned pilot does not incur.

4. Parking – [Post Landing]

a. **Common practices between UAS**
There were no detailed procedures for parking found in this research.

b. **Common practices between UAS and manned aircraft**
There were no detailed procedures for parking found in this research.

c. **Unique differences between UAS or UAS to manned systems**
There were no detailed procedures for parking found in this research.

5. Engine Shutdown – [Post Landing]

a. **Common practices between UAS**
There were no detailed procedures for engine shutdown.

b. **Common practices between UAS and manned aircraft**
There were no detailed procedures for engine shutdown.

c. **Unique differences between UAS or UAS to manned systems**
There were no detailed procedures for engine shutdown.

H. PROCEDURAL ROLES AND RESPONSIBILITIES RELATED TO PILOTS

a. **Common practices between UAS**
All systems required a minimum of one pilot to act as the RPIC.

b. **Common practices between UAS and manned aircraft**
All manned aircraft require at least one pilot to act as PIC. Some aircraft require a flight crew of more than one person; however, only one may act at the PIC.

c. **Unique differences between UAS or UAS to manned systems**
Although a UAS requires one PIC to operate the system, the PIC can change. With a UAS, the incoming PIC may not have participated in other phases of flight such as preflight, taxi, takeoff, transfer of control, or en-route operations, but may become the PIC later in a flight, such as a landing procedure. A crew-changeover briefing may take

place as the transfer of control between crewmembers within the same control station or different control station occurs.

In a manned aircraft, all of the crewmember must be on the aircraft during all preceding phases of flight. Crewmembers may participate in an initial crew briefing, but may also participate in a crew changeover briefing within the same cockpit.

Some systems require the use of an Aircraft Commander and/or Mission Commander in addition to a PIC.

I. CONTROL STATION HANDOFF AND PILOT CHANGEOVER DURING OPERATIONS

a. Common practices between UAS

Initially during this element of research task, consideration was only the control station handoff, which pertains to transferring control from one control station to another. This is typically completed in operations in which the aircraft is in a beyond line of sight (BLOS) environment. The nature of long-endurance UAS is such that crews may be scheduled in shifts. The transition of control from one pilot to another within the same ground station is referred to as a changeover. It was decided to expand this task to include crew changeover as well.

Regarding ground station handoff, since commercial regulations do not broadly encapsulate BLOS operations, little information is available outside of DoD assets. Within the DoD systems, little information regarding the transfer of control between remote ground control stations was available within the documents that were compiled for the literature review, with literature focusing primarily on crew changeover procedures within a control station.

Of the available information relating to control station handoffs between remote locations, the most detailed information was found in military UAS Operations Manuals. Handoff procedures included briefings and radio communication requirements. Similarities between control station handoff procedures were the most pronounced between the Air Force assets, referring to the aircraft operator’s requirement to complete required steps and follow the aircraft manuals and checklist.

Literature that focused on crew changeovers within the control station was primarily oriented towards a briefing for the incoming pilot that covers both normal and abnormal system behavior, identifying responsibilities during the transfer, and ensuring that control is not interrupted. These procedures ensure a smooth transition of control between pilots and the aircrafts status is known while preventing an interruption in aircraft control.

A common theme between all UAS handoff procedures is the importance of communication and the reliance on a checklist to guide the procedure. The emphasis on these elements of UAS operation highlight the importance of coordination and defined procedures when exchanging the information necessary to hand over control of a UAS to a pilot that will take over control from a remote location.

b. Common practices between UAS and manned aircraft

The chosen literature showed few similarities between manned and unmanned procedures relating to the transfer of controls between control stations. The closest comparison that can be made between manned and unmanned aircraft in terms of the transfer of controls in a UAS crew changeover procedures. However, these similarities are primarily superficial in that they involve the physical transfer of the control station from one pilot to another and require the aircraft's status and instrumentation to be monitored throughout the process. They do not address the handoff of controls to a control stations in a remote location, and do not allow for a direct comparison between the required procedures.

c. Unique differences between UAS or UAS to manned systems

There are obvious differences between manned and unmanned control transfer in that the unmanned aircraft has the capability to pass control of the system to a different physical location. This is entirely unique to unmanned aircraft and is due to the fundamental difference in how the two types of aircraft (manned and unmanned) are piloted.

The majority of the literature for unmanned aircraft systems highlights procedures and processes that relate to crew changeovers within a control station, with a smaller emphasis on transfer of control from one control station to another. Despite the limited information relating to control handoff between control stations, what is available highlights the importance of procedures for both events; a change of crew and a handoff to a different control station.

J. OPERATIONS DURING COMMAND AND CONTROL DEGRADATION AND LOSS

a. **Common practices between UAS**

Little information relating to procedures with degraded command and control performance was found in the literature. The most significant information relating to operations with degraded system performance came from Air Force doctrine and referenced the ability of the UAS to land with a degraded navigation solution, provided that the runway is suitable.

b. **Common practices between UAS and manned aircraft**

The literature showed no commonalities between manned and unmanned aircraft with respect to the operation of the aircraft with degraded or a loss of command and control.

c. **Unique differences between UAS or UAS to manned systems**

The literature was extremely limited in terms of describing procedures for degraded operation. This is especially true with respect to degraded command and control. The loss of primary command and control functions on the part of the pilot due to a lost-link scenario was better covered, but degraded performance and control loss due to other factors was not. This is not necessarily due to these procedures not existing, but instead points to a gap in the literature that may be addressed with greater access to system documentation and operations manuals.

K. OPERATIONS DURING PERIODS OF DECREASED DATA FROM AIRCRAFT ATTITUDE, PERFORMANCE OR ENVIRONMENT

a. Common practices between UAS

Degraded sensory cues may occur under two conditions. Partial or full downlink failure modes.

Partial or intermittent downlink failure modes occurred when the downlink stream was not consistent. The downlink reports from the unmanned aircraft (UA) may occur as interrupted messages from the UA to the Control Station (CS). The conditions may occur from multiple causes including failures with onboard datalink equipment; masking of the datalink stream between air data terminal and the ground data terminal; failures with the ground data terminal to the CS; downlink telemetry signal jamming. The pilot may be able to maintain awareness, although may experience periods of increased workload while performing emergency procedures to increase the downlink quality, or to move the UA to an area to eliminate masking. Additionally, the pilot may become disoriented as the CS is displaying intermittent data, such as inconsistent or erroneous UA status such as RPM or UA's position on scrolling map confusing the pilot.

Full downlink failure modes occur when the AV downlink is consistently disrupted. The downlink reports from the unmanned aircraft (UA) will occur as no report(s) from the UA to the Control Station (CS). The conditions may occur from multiple causes including failures with onboard datalink equipment; masking of the datalink stream between air data terminal and the ground data terminal; failures with the ground data terminal to the CS; downlink telemetry signal jamming, or an UA mishap (such as propulsion failure causing flight into terrain). The pilot is not able to maintain awareness because no telemetry is being reported (or received) into the CS. The pilot may experience periods of increased workload while performing emergency procedures to reestablish a downlink signal.

Common considerations for between UAS included the use of payload video, if available, to assist the pilot in understanding if uplink is still being received by the UA. In some UAS the payload video, if available, was used during emergency procedures to navigate the aircraft to a better location, return to home, or navigate to a flight termination location.

b. **Common practices between UAS and manned aircraft**

The manned aircraft has a back-up if the performance engines fail. The pilot can use 5 senses to track location, approximate speed, attitude and altitude. Many UAS also have a built-in, redundant back-up in lieu of not having the ability to rely on senses.

c. Unique differences between UAS or UAS to manned systems

UAS with operational payload video may be able to use the video to assist the pilot with understanding the status such as pitch, roll, and location of the UA; however, not all UAS have an independent full-motion video datalink. Some UAS have no full-motion video at all. Some UAS have a single downlink datalink which includes both telemetry and video.

Some UAS have redundant telemetry datalinks. Should a primary datalink fail, then a secondary datalink may enable the pilot to understand what the UA is doing during normal or emergency operations. For example, the primary datalink range may be limited to shorter distances, but uses a higher data bandwidth for launch and recovery operations. During en-route operations, the UAS may be operating on a secondary datalink under normal operations. Other UAS may operate under primary datalinks and the use of secondary datalinks may be considered emergency operations.

The pilot of a manned aircraft would be able to use other cues such as aural, vibration, and other instruments to continue flight with the loss of attitude or airspeed indications. The manned aircraft pilot has the ability to disengage an autopilot, if operational at the time of partial instrument failure, to manually control the aircraft using input from other information. A UAS pilot relies on the data to fly the aircraft and has no other outside cues to use as back-up if performance instruments degrade or fail.

L. LOST-LINK TROUBLESHOOTING PROCEDURES

a. Common practices between UAS

More research is desired on this topic; few sources contained information relating to lost-link troubleshooting procedures. Procedures within some documentation were rooted in over-arching doctrine, and were not specific to any particular platform as the example below:

"During this emergency, the UAS crew will attempt to reestablish communications with the unmanned aircraft. If contact is reestablished, the aircrew will decide whether to terminate the mission and return to base to preserve the asset or, based on the tactical situation, continue the mission as planned. At the return home side, the unmanned aircraft will perform the programmed flight recovery maneuver unless communications have been restored and the Air Vehicle Operator (AVO) commands otherwise."

This straightforward approach to lost-link troubleshooting paints a broad picture of how such procedures are frames. It is also likely that it relies on specific system documentation to further define what specific lost-link troubleshooting actions are.

While this general standard is geared towards operation in a tactical scenario, it is relevant in that it points to a baseline for how lost-link troubleshooting may be handled with any UAS, regardless of the operating environment. This general approach specifies that attempts should be made to regain control, and based upon the outcome of those attempts; the pilot should make a decision whether to continue the flight, land, or terminate the flight based upon the nature of the failure. If the link cannot be re-established, the UAS will fly its predetermined lost-link flight plan.

b. Common practices between UAS and manned aircraft

Manned aircraft are not subject to the same constraints associated with direct control through a data link and therefore does not have an equivalent lost-link procedure.

c. Unique differences between UAS or UAS to manned systems

UAS's are unique in a loss of the command and control (C2) link can render the pilot unable to directly influence the flight path of the aircraft. In the event of this kind of failure, the options available to a UAS pilot are often limited, and the UAS typically reverts to a predetermined state. This state is often to return to a suitable landing location.

Information relating to lost-link troubleshooting procedures for specific UAS was limited within the given literature. Further access to system documentation may help to fill these gaps. Checklists and manuals for specific UAS are expected to include any troubleshooting procedures and any additional information that the pilot needs to address a lost-link scenario, but given the nature of the systems that were evaluated for this literature review, this information is difficult to share due to the proprietary and/or confidential nature of the systems.

M. LOST-LINK PROCEDURES (following confirmation of lost link)

a. Common practices between UAS

Commonalities reflecting responses to lost-link conditions are highlighted in the higher-level doctrine that was reviewed. Best Practices share two common practices for addressing lost-link scenarios.

The first is in the event of a lost link, the pilot of the UAS should be in contact with ATC and ensure that their lost-link plan, whatever that may be, complies with any ATC clearance requirements.

The second is UAS behaves in a predictable manner after the link is lost, often following a pre-planned route.

In addition, FAA ATO Policy addressing lost-link scenarios further specify that specific transponder squawk codes should be used to broadcast a lost-link scenario to ATC independently of pilot radio calls.

Commonalities between UAS with respect to lost-link control, while not as clear in the literature, do exist. They all state the requirement of the UAS to follow some kind of "predicted flight path". However, lost-link procedures for specific UAS may differ based upon operating environment and conditions. The pilot will need to ensure the lost-link flight plan account for terrain, weather, and any restricted airspace along the route of flight.

b. Common practices between UAS and manned aircraft

Given the significant differences in how manned and unmanned aircraft are controlled, there are no commonalities between manned and unmanned aircraft in this respect. Policies propose that transponder codes be used to indicate lost-communication status of UAS using squawk codes. For UAS applications, this is a natural extension of common, accepted aviation practice that addresses the need to communicate a lost-link status quickly and allow ATC to adapt to the change.

c. Unique differences between UAS or UAS to manned systems

While it is known that all UAS considered within the literature have some form of lost-link control procedures, not all were present in the literature. This gap is largely due to the nature of the systems and their documentation. The procedures that were available varied in what the aircraft was programmed to do in the event it went lost-link. Some immediately climbed and headed back to landing airfield while others went into a holding pattern for a period of time before returning to an airfield. Other aircraft would start a descent to landing, while other aircraft had not logic pre-build in.

N. IN-FLIGHT EMERGENCIES

An in-flight emergency can be generalized when other-than-normal circumstances in performance occur that could lead to degraded ability to aviate, navigate or communicate with potential for loss of aircraft or life. Based on the severity of the situation the goal is to minimize the impact of the emergency to prevent loss of life and resources. Due to this common goal, it is not surprising the standards and procedures used in manned aviation have been closely adapted to current UAS operations. Any significant changes noted in research were driven by technology constraints and not due to a change in philosophy. The greatest deviation noted in the handling of an in-flight emergency between manned and unmanned aircraft was in UAS procedures it was noted several times where the PIC was trained to make the decision to terminate or ditch the aircraft verse doing a forced landing which could not ensure the safety of other manned aircraft, resources and infrastructure on the ground, or civilian lives. Having the absence of a soul on board made ditching and flight termination a greater outcome potential for an in-flight emergency on a UAS verse a manned aircraft where ditching would be an extreme last resort option.

1. Propulsion failure – [In-Flight Emergencies]

a. Common practices between unmanned system

Most UAS aircraft have been designed to get airborne and stay aloft with minimal power, therefore, they often have more of a glider design. The Altavian NOVA 7200 has a 12:1 glide ratio and the RQ-4 Global Hawk boasts a 131-foot wingspan as examples. The nature of most UAS designs allow the aircraft to be able to glide at a controlled rate for relatively long distances over time and therefore one of the first common steps during engine failure was to asses' ability to make it back to approved airfields or locate proper ditching locations. Though there is a sense of urgency in any emergency, a commonality between UAS platforms was having longer time prior to being on the ground in an engine out situation, allowing greater options for landing areas.

All UAS's under the scope of this research addressed had an engine failure/engine out checklist or procedure. Most still maintain electrical power to be able to maintain aircraft control for purposes of navigating and communicating. The other common standards and procedures were also shared with manned aircraft and are included in part b below.

b. Common practices between UAS and manned aircraft - In-Flight Emergencies

This is one of the most critical emergencies that could happen during flight so it was no surprise that many UAS's share similar procedures. There are many common shared practices.

As with manned aircraft, airmanship is the number one priority. Maintain aircraft control, continue to navigate, and communicate when safely able to do so remains a common core of airmanship between manned and UAS aircraft.

UAS rely heavily on detection and identification from the pilot as automation increases, verse flying the aircraft. Common areas included identifying a failure in a timely manner using indications displayed on flight instruments in the cockpit for a manned aircraft or ground station screen in an UAS. Identify any other systems or load shedding affected by losing engine propulsion. Additionally, identifying a landing sight the aircraft can safely glide to.

Other common skills addressed under this area were pilots' ability to reduce drag if applicable, communicate with ATC of the emergency to gain priority and traffic deconfliction while maintaining aircraft control, and squawk 7700 (this happens automatically on most UAS's like the RQs).

Also, the pilot of most UAS platforms researched were provided and required to complete engine failure/out checklists. Pilots were directed to continue to monitor instruments like airspeed, altitude and temperatures and with this emergency land as soon as possible at a suitable airfield.

c. Unique differences between UAS or UAS to manned systems

There was no research discovered on engine restarting procedures for UAS. Though this research didn't exhaust every design and UAS on the market, it can be confidently said most UAS's did not have restart capability after the engine failed. This is different than many manned aircraft that have the ability to try to restart a failed engine.

One of the main themes shared in an engine out checklist for UAS was to ensure route and waypoints to the landing or termination were safely away from people or property. In a manned aircraft, though safety of civilians were noted scarcely upon picking a suitable runway, there were no noted implications/restrictions of picking a flight path to that location over areas of population. This is logical as the difference is the consideration of getting souls on board safely to landing verse no consideration of souls on board in a UAS and therefore less risk should be taken to secure a landing for a UAS.

The S in UAS is for systems, which speaks to the architecture of unmanned flight. There is Mission Control elements and ground support built into the architect. A pilot on a manned aircraft only needs to relay the emergency to ATC prior to landing. The UAS operator will also inform mission commanders, SOF (supervisor of flight), ground support crews and time permitting may even call a response center. Some larger contractors make response centers available which has on call experts to help troubleshoot information. In some UAS infrastructures there are different landing/takeoff control elements (LRE) and/or pilots that would need to be coordinated with quickly to "catch' the aircraft on final. Often there are more resources and members involved in a UAS emergency then the single pilot flying in a manned aircraft would have access to.

On manned aircraft, there will be a quick check of seat backs in the most upright position and secure seat belts/harnesses. These steps would not be required on an unmanned aircraft.

There was no research discovered on fuel jettison procedures for the UAS's under the scope of this research. Though for engine-on emergencies, included in the checklist were burn-down fuel procedures as the unmanned platform would be able to maintain altitude to afford the opportunity to lessen weight on the landing, it was not noted in any of the procedures for engine-out. This was a listed for consideration in manned aircraft engine-out procedures

2. Emergency Descent – [In-Flight Emergencies]

a. Common practices between UAS

UAS architecture allows for other members to help decrease task saturation during an emergency. The ground station affords access of resources outside of the virtual cockpit. Most platforms had other personnel readily available during operations to include a sensor operator, mission commander, and shelter maintenance personnel. These crewmembers can be delegated to execute tasks such as obtaining weather, communicating with ATC and other outside agencies, pulling up airfield diagrams, reading checklists, etc., to allow the pilot to remain focused on maintaining positive aircraft control, monitoring other aircraft systems and navigating to a landing area. Some UAS platforms additionally have extra pilots already on site to provide physiological breaks during the course of the sortie.

As with normal en-route descents, requirements reviewed for UAS indicated a focus on the ability of the PIC to anticipate the airspeed, altitude, and heading of future waypoints and to plan their descent accordingly while monitoring system health (e.g. pitch indications, proper airspeed and altitude responses, vertical speed and engine indicators). A noted difference found was based on the level of autonomy assisting in the descent. In an emergency situation a pilot must be aware of built in actions points along the mission route that may trigger additional actions based on the state or contingency the aircraft is in. Noted on one UAS platform, when put into a C-3 condition (emergency condition), the aircraft automatically shuts down the engine upon reaching the Initial Approach Point (IAP), which eliminates the ability for the aircraft to execute a missed approach. It is crucial the pilot is aware of these action points and has the knowledge to override them when absolutely necessary.

b. Common practices between UAS and manned aircraft

Both unmanned and manned systems standards and procedures call for the PIC to understand and operate within the performance envelope of their aircraft. The need to plan descents with future waypoints or procedures in mind while monitoring system health is also universal. This remains true in an emergency with the caveat of working with ATC to gain traffic priority in the descent to ensure aircraft can maneuver to quickly get on the ground, especially in cases where the longer airborne the more exasperated the emergency becomes such as a fuel or other fluid leak.

c. Unique differences between UAS or UAS to manned systems

As earlier mentioned on some UAS platforms, the mission control ground station pilot is not the same as the take-off/landing control ground station pilot, as earlier referred to as split operations. Though these systems are capable of having the mission control pilot land the aircraft, it can come at a degradation of capability and/or skill. The take-off and landing ground station (LRE) is the only ground station with line of sight links such as UHF LOS. This allows more immediate control from the pilot's command to the aircraft maneuvering. The mission control ground station (MCE) uses beyond line-of-sight links, which have a delay between pilot's command and aircraft maneuver. In a critical environment where LOS links are available, it is desirable to have the LRE station and pilot fly the aircraft for descent and landing to have the most immediate response to pilot's input. Therefore, unlike manned aviation, in regular procedures and emergency the LRE pilot and ground station would be brought on line and "catch" the aircraft, time permitting, which would require the extra step of doing a "hand-over" brief from one pilot and station to the other.

Other UAS platforms, there are often different currencies and/or certifications, which vary from platform to platform. There is the potential the pilot in control during the cruise/mission phase when an emergency arises that requires the aircraft to be landed as soon as possible is non-current and/or not certified to land the aircraft. In this case a hand-off to a certified or current pilot would be the normal practice, time permitting. In a manned aircraft, the pilot would have all required certifications and currencies and the only equivalent practice would be to have the most experienced/skilled pilot fly the aircraft, if more than one is available.

Some UAS platforms have a ground observer as part of their architecture. In lieu of a full-motion video capability (FMV) these platforms rely on a spotter to verify the aircraft is lined up on the correct landing runway, in the correct configuration and glide pattern, and the runway/taxi area is cleared of people and other obstacles. In a landing emergency, it will be important to get the visual observer back out on the airfield to perform these duties. If the visual observer is unavailable, at locations where there is a control tower, coordination can be made with the tower to be the visual observer.

As mentioned earlier under in-flight emergencies, the emergency descent of a UAS as a glider designed aircraft often would have more time in the descent to run full checklists and seek the assistance of the Mission Commander and other resources to help with checklist execution and communications with ATC. There could be multiple airmen helping to resolve the problem to safely get the aircraft recovered verse a manned aircraft where the pilot may be the only person available responsible for obtaining weather, ATIS, communicate with ATC, study approach and landing, etc. and therefore have the potential to become more greatly task saturated under emergency situations.
A manned aircraft takes an exponential amount of attention verse a UAS to maintain positive aircraft control. Parameters such as radius of turns ¼ to 1/3 mile from reference points, bank angles to not exceed 60 degrees, establish 68 KIAS on descent, maintain step altitudes on descent +/-100 feet, airspeed +0/-10 knots, are all criteria which require tentativeness and skill that can be compromised when dealing with other emergency situations that also require extra procedures, steps, or monitoring. The automation built into some UAS platforms and preprogrammed mission points allows the aircraft to automatically maintain the correct airspeed, altitude and performance parameters allowing the pilot to monitor verse control which decreases task saturation.

Manned aircraft requirements also have considerations that would generate an emergency descent not necessary for UAS. Depressurization and cockpit smoke are examples, additionally during the descent the requirement to maintain positive load factors was addressed only in manned operations.

3. Emergency Landings – [In-Flight Emergencies]

Communication – Emergency Landings – [In-Flight Emergencies]

a. Common practices between UAS

In general, there were no common practices identified on communications during an emergency across platforms. The expectations remained the same as normal operations and aligned with 14 CFR 91.129 (i).

The communication between the Launch and Recovery Element (LRE) and the Mission Control Element (MCE) remain essential in an emergency ensuring smooth transition of aircraft control and to keep updated on any changes in expected times for the scheduled, or non-scheduled transition to occur.

Few platforms required establishing notification procedures and communication connectivity between the operation center and emergency airfields as well as making contact with those able to ensure the landing runway was clear of personnel/aircraft/and equipment.

For UAS that do not fly BLOS, the need for the operator and observer landing to remain co-located and communicate verbally remain in an emergency.

b. Common practices between UAS and manned aircraft

In general, there were no additional common guidance and requirements identified on communications during emergency but the expectation to continue 14 FR 91.129 (i) requirements listed below.

UAS and manned aircraft both require an operator to exhibits the knowledge, and skills to communicate with Air Traffic Control (ATC) for clearances and procedures within the National Airspace System (NAS). The skill to use and understand the proper phraseology and to correctly copy, read back, interpret, and comply with an ATC clearance is common between platforms.

Knowledge and skills are required to correctly set up communication frequencies, navigation systems and transponder codes in compliance with the ATC clearance along with monitoring proper frequencies, including emergency frequencies.

c. Unique differences between UAS or UAS to manned systems

Manned aviation systems do not have unmanned aircraft systems remote split operations. This adds an additional layer of communication during emergency landing between the landing crew and mission crew with UAS's of this capability.

UAS's, which have sensor operators or other crewmembers that provide additional back up during landings, become even more critical during an emergency. Some platforms the sensor operator is to notify the pilot of air traffic conflict or deviations in altitude. Additionally, each aircrew member will monitor the crew intercom and aircraft radio to maximum extent possible.

The ground stations have the ability to use a telephone. It is procedure for the MQ-1/9 and other platforms to minimize uses during critical phases of flight.

The sensor operator or additional crewmembers afforded to a UAS pilot during an emergency also will inform the pilot of any additional caution and warning messages.

In the case of some UAS platforms, such as the RQ-4, an emergency mission plan with predetermined routes and altitudes are programmed into the aircraft logic. A pilot must be able to determine what contingency the aircraft is in and accurately predict what actions the aircraft will take, to include direction of turn, altitude it will climb or descend to during phases of flight, and the emergency flight route.

Approach – Emergency Landings – [In-Flight Emergencies]

a. Common practices between UAS

There were no common practices between UAS for emergency procedures during an approach. The research concludes in an emergency; the common approach requirements remain the same as normal operations listed below time permitting:

1. Verify fuel/flight time in case of go-around
2. Review approaches and go-around options via chart or mission planning tools
3. Review and establish descent rates, weather, obstacles, etc. prior to commencing approach.

b. Common practices between UAS and manned aircraft

During this phase of flight, approach to landing, the UAS and manned aircraft share the common goal of transitioning safely to landing and therefore the procedures are aligned in regard to executing checklist, receive proper ATC clearance to continue on approach and be aware of all go-around/missed approach procedures.

c. Unique differences between UAS or UAS to manned systems

There are several unique procedures between manned and unmanned aircraft. The unmanned procedures in some cases reference mission planning tools whereas manned procedures do not use a mission planner or GCS.

In a UAS, the pilot can identify and seek waiver authority in the case of an emergency for landing below minimum weather or other stated requirements.

The UAS pilot will ensure if unable to comply with the missed approach routing or climb requirements, coordination for alternate climb out instructions are made which ensures obstacle clearance.

For an engine out emergency, a UAS pilot will identify safest ditching/termination point if a safe landing can't be made while on the approach, or when directed to abort landing/go-around by ATC due to safety of life or resources.

For UAS's that do not include approach procedures, a standard approach procedure should be developed with standard and emergency approach methods included.

Touchdown – Emergency Landings – [In-Flight Emergencies]

a. Common practices between UAS

There were no specific procedures or standards noted in landing with an emergency besides the execution of all emergency and landing checklist prior to landing. There continued to be verbiage about UAS not landing in areas where potential life or resources could be put in danger.

b. Common between UAS and manned aircraft

For aircraft that included procedures for landing, the procedures were similar between UAS and manned. Both required the aircraft be configured for the landing phase, review and completion of landing checklists, communicate and verify ground crews were ready, confirm clearance with ATC was given, and then initiated the landing.

When conditions permitted, completion of both emergency and normal landing checklists were expected.

c. Unique differences between UAS or UAS to manned systems

Due to the lack of procedures for landing in both manned and unmanned, no unique differences can be highlighted.

Ditching Site Selection – Emergency Landings – [In-Flight Emergencies]

a. Common practices between UAS

Ditching an aircraft, for the purposes of this research, is an aircraft that is still able to maintain some level of positive control while landing, but unable to safely make a designated or approved aircraft-landing surface. Ditching, verse flight termination, also assumes an attempt is being made to minimize damage to the aircraft and/or safety of the crew on board. Only common standard and requirement noted in the very few UAS's that had standards or procedures for ditching were to ensure the primary site selected would not endanger personnel or property on the ground.

b. Common practices between UAS and manned aircraft

There were very specific ditching procedures for manned aircraft based on type of aircraft and ability to carry passengers and/or cargo. However, no commonalities were found between UAS and manned operations, mostly due to the lack of procedures and standards for UAS ditching.

c. Unique differences between UAS or UAS to manned systems

The requirement to not ditch in a place where any risk property or safety of life could be jeopardized was not a stated standard or procedure for manned aircraft.

Manned aircraft ditching procedures also included securing cargo and briefing passengers, to include proper impact positions and emergency exit procedures upon landing. Water ditching had additional requirements on releasing and using safety rafts for manned aircraft. These would not be procedures necessary to be adopted by current larger-than-small UAS platforms.

Flight Termination – Emergency Landings – [In-Flight Emergencies]

a. Common practices between UAS

Flight termination for this research is when an aircraft is purposefully put into a spin or other unrecoverable flight parameter to ensure the aircraft impacts the desired area. Unlike ditching, the aircraft is expected to be a complete loss. The choice to terminate is most often due to the aircraft not being controllable for landing, or a suitable airfield cannot be made safely given the remaining battery supply and/or altitude. Technology for UAS to flight terminate was different from platform to platform. The commonality was the emphasis to find a location that ensured safety of other aircraft, resources, and life.

b. Common practices between UAS and manned aircraft

There were no flight termination procedures or standards available for manned aircraft. The closest procedure a manned aircraft would have is to put the aircraft into an intentional spin to minimize distance it would fly prior to impacting the ground, thus providing more assurance of it crashing where desired. However, with a person in the aircraft it would be assumed a ditching option would be selected over a flight termination, as this would also translate into a life termination procedure as well.

c. Unique differences between UAS or UAS to manned systems

None were noted as there were no termination standards or procedures for manned aircraft discovered in this research to compare to.

4. Uncontrolled flight (where real time human pilot input, either manual or through automated systems, has no effect on the aircraft attitude or flight path.) – [In-Flight Emergencies]

a. Common practices between UAS

UAS platforms rely on a control links such as UHF, SATCOM, KU and/or Inmarsat to be able to relay commands. A common procedure when a pilot has no ability to change aircraft attitude or flight path is to switch over to another control link if available to help troubleshoot the lack of response.

There are various degrees of automation in UAS platforms and uncontrolled flight can be causal due to control link failure, mechanical failure, or pilot error. In all cases it is up to the UAS operator to troubleshoot the cause and try to put the aircraft back into the controlled flight envelope.

There were no commonalities between procedures across UAS in regards to recovering an aircraft from uncontrolled flight. Data that was found for uncontrolled flight situations was very limited. There were checklists in several UAS and others that addressed troubleshooting to regain command control. Spin and stall recovery checklist were present in a few publications. In one highly autonomous UAS the pilot doesn’t have the ability to recover the aircraft outside of controlled flight and only had checklist for mechanical and control link failures. The automation levels were too divergent across platforms to draw common practices. Some platforms autonomously control all of its flight parameters such as rate of climb, turn, and level-off, while others are flown with a stick and rudder.

b. Common practices between UAS and manned aircraft

The inability to control aircraft attitude or flight path for manned aircraft is due to either a mechanical failure of a control surface or the aircraft was flown outside its parameters to maintain controlled flight (stall or a spin). The only common procedures found between UAS and manned were in regards to uncontrolled flight caused by the aircraft being flown outside its parameters to maintain controlled flight.

Unusual flight attitudes that can lead to uncontrolled flight can result from stress, high workload, task saturation, and distractions. These contributors are experienced by both UAS and manned pilots.

c. Unique differences between UAS or UAS to manned systems

The automation levels of some UAS aircraft were designed to keep it in its flight envelope. More developed UAS platforms have constant feedback from numerous sources to eliminate the pilot from being able to stall or put the aircraft in a spin. It will override commands from the pilot to increase/decrease power, increase/decrease climb/descent, or increase rate of turn. It uses optimal performance data while flying and pilots can only direct final altitude, final heading. The level of automation eliminated a pilot from being able to command the aircraft into an uncontrolled flight parameter unless flight termination was selected.

Manned aircraft have the benefit of the pilot in the aircraft using all senses while flying. A pilot can feel when the aircraft it climbing, descending and/or turning. This is not a benefit a pilot sitting in a ground station has. It can be concluded it is easier for a pilot in a manned aircraft to sense he/she is approaching an uncontrolled flight situation, or is in an uncontrolled flight situation, verse a person staring at a screen who may be distracted at looking at weather, chat windows, moving map, or other external factors.

There are physiological situations that can lead a manned aircraft into an unusual attitude and/or uncontrolled flight such as spatial disorientation or the leans. These are not generally concerns for a UAS pilot operating out of a ground station.

5. Navigation (GPS or other navigation system) failure – [In-Flight Emergencies]

a. **Common practices between UAS**

UAS technology and platform reliance on internal navigation varied so widely, to include redundancy and back-up systems that no commonality could be assessed. There was a varied degree of possible safe recovery of aircraft based on navigation failure.

b. **Common practices between UAS and manned aircraft**

UAS and manned aircraft have procedures to use external references and ATC radar to assist in location of the aircraft and use pilotage to get to landing area. The use of ground data azimuth and dead reckoning is similar with platforms. Computing time, distance, and heading for each leg of flight route, and using assistance of ATC radar or visual observer was shared between platforms.

c. Unique differences between UAS or UAS to manned systems

There were a few systems that had built in contingencies for loss of navigation. One UAS researched will enter into a 20-degree roll, orbiting clockwise, maintaining current altitude. The aircraft would descend as it maintained a 20-degree roll until it reaches the surface if it doesn’t regain GPS inputs. Another UAS researched will also enter an orbit if it loses all internal navigation inputs. This is a design to allow time to troubleshoot the navigation problem.

A unique difference between most UAS and manned aircraft is once a manned aircraft has successfully reached a landing field after a loss of internal navigation, the emergency is averted as the landing process in VFR conditions remains the same as standard operations. Most UAS platforms rely heavily on internal navigation for landing, especially those designed to land autonomously. To override automation and have to manually land the aircraft is still an emergency situation for the more autonomous platforms.

APPENDIX B—INITIAL RECOMMENDATIONS BY TASK

To accommodate the reader's varied interest in the literature review during the PC-1 task of this research, this appendix was organized by each task concentrating on 'Initial Recommendations". Initial recommendations were not the proposed recommendations, but current research regarding available standards and procedures.

A. PREFLIGHT

1. Before Entering GCS – [Preflight]

Initial Recommendations

a. Require the pilot to become familiar with all available information concerning each flight, including weather, NOTAMS, flight plan, told data, alternate landing sites, and alternate airport fuel requirements.

b. Require pilot proficiency areas in checklist usage; ability to properly identify aircraft discrepancies; procedures for deferring inoperative equipment; proper fuel and oil servicing.

c. Require the pilot to perform fuel planning to ensure the aircraft is carrying enough usable fuel on each flight. Plan a reserve fuel based on a percentage of at least 10% of the planned flight time or a minimum reserve time of 30 minutes.

d. Require each pilot and crew, to include visual observer, hand-over crew, launch/recovery specialist, and maintenance personnel to do a crew resource management check and/or brief to determine human factors risk for flight.

2. Before Engine Start – [Preflight]

Initial Recommendations

a. Require the pilot to verify the functionality of the aircraft, control station, and support equipment through a methodological process.

b. Require the pilot to evaluate the functionality of avionics, sensors, actuators, lighting, flight control surfaces, servo actuators, datalinks, fuel, and oil levels.

c. Require the pilot to detect possible defects for aircraft, control station, and support equipment.

d. Require the pilot to verify the functionality of the emergency/contingency mission plan.

e. Require the pilot to verify the UAS meets the minimum equipment list for flight.

f. For UAS with multiple crewmembers, verify the functionality of communication systems.

g. Require the pilot to document any defects noted, limitations as a result of missing or non-functional equipment on a standardized form.

h. Require the pilot to document the completion of the preflight inspection.

i. Require the pilot be able to use radios and demonstrate use of correct verbiage when getting current ATIS information and requesting engine start/clearance on request with airport ground control.

j. Require the pilot be familiar with any existing cold or hot weather starting procedures and/or standards for the aircraft and exercise correct action when operating inside one of those conditions.

3. Engine Start – [Preflight]

Initial Recommendations

a. Require the pilot to establish two-way communication with ground support crewmembers.

b. Require the pilot to perform engine starting procedures through a methodological process.

c. Require the pilot to verify throttle position prior to engine start, if capability exists.

d. Require engine health information to be monitored during engine start. In circumstances when a pilot is unable to establish a link connection to the aircraft to monitor engine health, a ground crew member is required to monitor engine health information until pilot establishes a link to take over these duties.

e. Require the pilot to change the throttle position during an engine run to verify normal operating parameters at other-than-idle RPMs, if capability exists.

f. Require the pilot to be able to demonstrate the ability to perform abnormal starting procedures.

g. Require the pilot to be able to demonstrate the ability to detect unsafe engine parameters.

h. Require the pilot to be able to immediately shut off the engine, if required.

4. Pre-Taxi – [Preflight]

Initial Recommendations

a. Require the pilot to determine if ice exists or if de-icing procedures are required prior to taxi operations.

b. Require the pilot to communicate with ATC to receive taxi instructions.

c. Require the pilot to set the UAS avionics systems correctly and in a methodological manner.

d. Require the pilot to correctly set the flight instruments.

e. Require the pilot to perform a pre-taxi briefing to all crewmembers.

B. TAXI

1. Communication and Pre-takeoff checks

Initial Recommendations

a. Require the pilot to maintain a sterile cockpit environment during all critical phases of flight.

b. Require the pilot to communicate with ATC using proper and accepted terminology.

c. Require the pilot to taxi in accordance with ATC instructions.

d. Require the pilot to perform a brake check as soon as safely can be executed based on aircraft technical data.

e. Require the pilot to be able to perform a full stop at any given time, whether self-initiated or directed to do so by ATC or visual observer.

f. Require the pilot to maintain a reliable datalink with the aircraft. Pilot shall be able to perform a switch link procedure to use the most reliable datalink when capabilities exist.

g. Require the pilot to use visual aids to taxi or be in two-way communication with visual observer.

h. If a marshaller is used, require the pilot to have two-way communication with the marshaller.

i. If a marshaller is used, require the pilot to taxi at a normal walking speed. If a safety observer is in a follow-vehicle, pilot shall taxi at a safe speed for conditions.

j. Require the pilot or visual observer to recognize hazards on the taxiway surface.

k. If the pilot is using Full Motion Video for taxi and loses sight of the taxiway centerline, the pilot must be able to stop the aircraft until visual contact with the centerline is reacquired.

l. Require the pilot to taxi at safe speeds for conditions present.

m. Require the pilot to taxi at a safe distance from other aircraft.

n. Require the pilot have knowledge of limitations for taxi for their airframe to include wind, temperature and RVR.

C. TAKEOFF

1. Communications – [Takeoff]

Initial Recommendations

a. Require, prior to taking the runway, that the pilot clears the approach path and runway through visual observer or other means.

b. Require the pilot to communicate using standard aviation/ATC phraseology, and adhere to standard ATC “read-back” requirements.

c. Require communication with a controlling agency prior to takeoff; following instrument departure communication procedures as appropriate

d. Ensure that a contingency is in place for a radio communications failure and that the pilot is proficient in its implementation.

2. Takeoff – [Takeoff]

Initial Recommendations

a. Require the pilot to make a final check of aircraft systems and configuration prior to requesting permission from ATC for takeoff (aircraft flaps, communications and datalinks, engine, and other required equipment).

b. Require the pilot or visual observer perform a final check of runway and airspace prior to initiating the takeoff run to ensure the runway and flightpath is clear of traffic.

c. Require the pilot to check solid command and control links prior to initiating takeoff.

d. Require pilot to acknowledge takeoff clearance in communications with ATC once takeoff approval has been received.

e. Require pilot to monitor the aircraft performance indications during the takeoff roll.

f. Require the pilot maintains runway heading.

g. Require the pilot to have knowledge of performance indications and verify engine is at full power and operating within established parameters.

h. Require pilot to monitor primary navigation or critical aircraft systems. Pilot must be able to recognize and perform proper procedures if aircraft falls outside of performance envelope.

i. Require the pilot to demonstrate proper ability to perform and abort the takeoff shall a safety critical failure occur during the takeoff roll.

3. Ground support – [Takeoff]

Initial Recommendations

a. Require the use of ground personnel to assist in takeoff if the UAS is not equipped with sensors that allow for the pilot to visually ensure that taxiways, runways, and parking locations are clear of traffic prior to takeoff.

4. Aborted/rejected takeoff – [Takeoff]

Initial Recommendations

a. Require the pilot to recognize when an aborted takeoff is required per technical guidance.

b. The pilot must know the minimum required airspeeds at which the UAS may be controlled while still on the ground or when out of ground effect and flying.

c. Require the pilot to maintain control of the UAS upon initiating an abort. This includes maintaining glide speeds and executing appropriate maneuvers in the event of an airborne abort.

d. The pilot must know the airport environment, including the available runway distance and obstacles within 30° of the runway heading.

e. Require the pilot to communicate an aborted takeoff to ATC when safety permits.

f. Require the pilot to confirm with visual observer if it is safe to taxi clear of the runway (hot brakes, smoke from engine, or other indications the aircraft needs to be shutdown immediately).

g. Pilot must be familiar with airport protocol when declaring an emergency for shutdown on runway and request assistance as necessary from fire department.

h. Pilot will contact maintenance or tow crew to expedite removing aircraft from runway when it is unable to be taxied after an abort or landing.

D. CLIMB-OUT

1. Climb-Out – [Climb-Out]

Initial Recommendations

a. Require the pilot to be familiar with the climb performance of the UAS being flown, including all relevant V-speeds (V1, VROT, VX, and VY).

b. The pilot must know the climb limitations of the UAS for the purpose of obstacle avoidance.

c. Require the pilot to be proficient in instrument flight rules, in this case, departure procedures (SIDs and Obstacle Departures).

d. Require the pilot to possess relevant instrument departure plates and necessary charts within the control station.

e. Require the pilot be able to execute climb-out checklist instructions such as raise the gear and flaps as required.

f. Require the pilot to be capable of complying with ATC guidance to include, switching the radio to departure, and/or turn/climb/level-off to directed heading/altitude.

E. EN-ROUTE OPERATIONS

1. Communications – [En-route]

Initial Recommendations

a. During all phases of flight, the operator must be aware of, and be able to monitor communication frequencies for ATC and comply with ATC clearance.

b. During the transition portions of the en-route phase the operator must have the knowledge and skills to communicate with the Launch and Recovery Element (LRE) or the Mission Control Element (MCE), which ever one is applicable.

c. Pilot must be able to execute proper hand-over procedures between PIC and/or LRE/MCE shelters.

2. Navigation (including GPS availability) – [En-route]

Initial Recommendations

a. Pilot shall demonstrate the appropriate level of knowledge and understanding of installed electronic navigation system(s), elements related to navigation systems and radar services, and elements related to pilotage and dead reckoning.

b. Pilot shall demonstrate knowledge of responsibilities associated with accepting an ATC clearance to include proper use of aviation phraseology, methods used to obtain an ATC clearance, knowledge of ATC airspace requirements, and read back ATC clearance.

c. Pilot shall demonstrate knowledge of RNAV, RNP, and TCAS procedures along with knowledge of transponder (Mode(s) A, C, and S) and navigation publications and databases.

d. Pilot shall demonstrate proper knowledge of lost communication procedures, and terrain clearance requirements associated with en-route navigation procedures.

e. Pilot shall demonstrate appropriate knowledge and use of the airborne electronic navigation system, and be able to locate the airplane's position using available and appropriate navigation system(s).

f. Pilot shall demonstrate skill to navigate by means of precomputed headings, groundspeeds, and elapsed time. Additional navigations skills include being able to recognize and describe the indication of station, or waypoint passage, and verify airplane's position within prescribed nautical miles of flight planned route.

g. Pilot shall be able to recognize navigation signal loss and be able to take appropriate action.

h. Pilot must correctly set up communication frequencies, navigation systems and transponder codes in compliance with the ATC clearance.

i. Pilot must establish two-way communication with the proper controlling agency, in a timely manner, and use standard phraseology.

j. Pilot shall have the ability to identify, assess and mitigate risks, encompassing automation management for task management, degraded awareness, limitations of navigation systems, and avoidance of automation distractions.

3. En-route climb – [En-route]

Initial Recommendations

a. PIC must understand climb performance of the aircraft and how to adjust it when able.

b. PIC must be able to notify ATC if aircraft climb performance does not meet minimum standards for instrument flight.

4. En-route descents – [En-route]

Initial Recommendations

a. Pilot must understand descent performance of the aircraft and how to adjust it.

b. Pilot must understand and be able to operate within aircraft operating limitations.

c. Pilot must be able to execute all descent checklists, to include hand-off checklists with LRE.

d. Pilot must have the knowledge and ability to communicate with ATC with request to conduct en-route descent.

5. Cruise power settings – [En-route]

Initial Recommendations

a. During all phases of flight, the operator must be aware of and able to monitor aircraft performance such as range and endurance.

b. Pilot must exhibit satisfactory knowledge, risk management, and skills associated with IFR departure, en-route, and arrival operations.

c. Pilot must understand and be able to utilize alternate power sources and related limitations associated with their uses.

d. Operator must understand various conditions that may affect range and endurance of an aircraft and be able to stay within aircraft and regulatory limitations.

e. Operator must be able to determine the effect of cruise performance on the aircraft shall airspeed, altitude, or other variables change en-route.

f. Operator must be able to determine new performance capabilities/limitations if a flight plan is altered due to change in purpose of flight, directed by ATC, or an emergency arises.

F. LANDING

1. Initial Descent

Initial Recommendations

a. The pilot must establish two-way radio communications with the ATC facility providing air traffic services prior to entering that airspace and thereafter maintain those communications while within that airspace.

b. Due to the current nature of UAS operations it may be necessary to create more detailed procedures with guidance for controlled and uncontrolled airspace and operations with specific step by step guidance on contact and clearance procedures.

c. The pilot conducts descent checklist.

2. Transition

Initial Recommendations

a. Pilot shall be aware of aircraft performance and the environment requirements of which they are transitioning through.

b. If a visual observer is required for landing to confirm configuration, proper runway alignment, and visually clear the approach path and landing runway, pilot must establish contact and be able to give an arrival time to ensure member is in place.

c. Pilot will contact maintenance and inform them of estimated land time in order to tow aircraft when required or assist in parking/shutdown as needed.

3. Approach

Initial Recommendations

a. Pilot must be able to execute all appropriate checklist associated with descent and before landing.

b. Pilot must be able to access proper weather sources for updates to landing airfield, to include current altimeter setting and winds.

c. Pilot must be able to communicate with ATC using proper terminology to request desired approach, state intentions (landing, touch-and-go), and receive approval to commence and continue approach.

d. Require the pilot to maintain a sterile cockpit environment during all critical phases of flight.

4. Landing (Non-Automated – Human in the loop) - – [Landing]

Initial Recommendations

a. Pilot must be able to execute all applicable landing checklists.

b. Pilot must be knowledgeable of landing weather minimum criteria and be able to identify alternate airfields if outside the required minimums.

c. Pilot must be able to brief and execute missed approach or go-around procedures when applicable.

d. Pilot must be knowledgeable of landing fuel requirements and know when to declare minimum and emergency fuel to landing controller.

e. Pilot must be able to recognize when aircraft is outside of landing parameters and be able to execute a successful missed approach procedure.

f. Pilot must be knowledgeable of the proper landing configuration and verify aircraft is configured to land.

g. Pilot must be able to communicate with ATC using proper terminology and read back to receive permission to land aircraft.

h. Pilot must be able to communicate with ground support crew to ensure landing configuration and proper alignment when applicable.

i. Require the pilot to maintain a sterile cockpit environment during all critical phases of flight.

5. Landing (Automated Approach and Landing) - [Landing]

a. Pilot must be able to execute all applicable landing checklists.

b. Pilot must be knowledgeable of landing weather minimum criteria and be able to identify alternate airfields if outside the required minimums.

c. Pilot must be able to recognize criteria for an autonomous go-around and communicate those procedures with ATC when the aircraft executes a go-around.

d. Pilot must be knowledgeable of landing fuel requirements and know when to declare minimum and emergency fuel to landing controller.

e. Pilot must be able to take over manually from an autonomous landing when directed to by ATC or safety dictates.

f. Pilot must be knowledgeable of system limitations and know when a command to go-around will be denied by the aircraft based on too low of an altitude.

g. Pilot must be knowledgeable of the proper landing configuration and verify aircraft is configured to land.

h. Pilot must be able to communicate with ATC using proper terminology and read back to receive permission to land aircraft.

i. Pilot must be able to communicate with ground support crew to ensure landing configuration and proper alignment when applicable.

j. Require the pilot to maintain a sterile cockpit environment during all critical phases of flight.

Initial Recommendations

a. Standard checklist for UAS landing procedures is developed for each variant of landing, size, and category that may be used as a standard for customization.

6. Go around

Initial Recommendations

a. Pilot must be able to determine risk and initiate a missed approach procedure when required.

b. Pilot must be able to communicate intent with ATC during a go-around and comply with ATC guidance when safely able.

c. Pilot must be able to apply proper, smooth power and correct climb attitude during a go-around.

d. Pilot must be able to climb to a safe altitude

e. Pilot must be able to reposition the aircraft to begin approach, transition to alternate landing area or request holding airspace to troubleshoot a malfunction.

f. Pilot must be able to execute proper checklist associated with a go-around procedure.

7. Ground support – [Landing]

Initial Recommendations

a. Pilot must establish two-way communication with ground support crew.

b. Pilot must be able to brief ground support crew on standards for landing and post-landing procedures.

G. POST LANDING

1. Communications – [Post Landing]

Initial Recommendations

a. Pilots must be able to use correct terminology and request permission to taxi clear of runway, and continue taxi to parking.

2. Ground support – [Post Landing]

Initial Recommendations

a. Pilot shall verify with ground crew the location of parking and ensure the safety of that location from damage or conflict of other aircraft.

b. Pilot shall communicate with ground crew to secure the aircraft.

c. Pilot shall be able to conduct shutdown checklists and post flight operations.

d. Pilot shall communicate the shutdown has been completed with ground crew and set a time for debrief as applicable.

e. Pilot shall accurately pass along any information they require to fill out all post-flight documentation.

3. Taxi – [Post Landing]

Initial Recommendations

a. Require the pilot to maintain a sterile cockpit environment during all aircraft movement.

b. Require the pilot to communicate with ATC using proper and accepted terminology.

c. Require the pilot to taxi in accordance with ATC instructions.

d. Require the pilot to be able to perform a full stop at any given time, whether self-assed or directed to do so by ATC or visual observer.

e. Require the pilot to maintain a reliable datalink with the aircraft. Pilot shall be able to perform a switch link procedure to use the most reliable datalink when capabilities exist.

f. Require the pilot to use visual aids to taxi or be in two-way communication with visual observer.

g. If a marshaller is used, require the pilot to have two-way communication with the marshaller.

h. If a marshaller is used, require the pilot to taxi at a normal walking speed. If a safety observer is in a follow-vehicle, pilot shall taxi at a safe speed for conditions.

i. Require the pilot or visual observer to recognize hazards on the taxiway surface.

j. If the pilot is using FMV for taxi and loses sight of the taxiway centerline, the pilot must be able to stop the aircraft until visual contact with the centerline is reacquired.

k. Require the pilot to taxi at safe speeds for conditions present.

l. Require the pilot to taxi at a safe distance from other aircraft.

m. Require the pilot have knowledge of limitations for taxi for their airframe to include wind, temperature and RVR.

4. Parking – [Post Landing]

Initial Recommendations

a. No recommendations at this time.

5. Engine shutdown – [Post Landing]

Initial Recommendations

a. Pilot must be able to execute all engine shutdown checklists.

b. Pilot must be able to communicate properly with ground support crew during engine shutdown procedures.

c. Pilot must be able to expeditiously shutdown the engine in case of an emergency during the engine shutdown process.

H. Procedural Roles and Responsibilities Related to Pilot

Initial Recommendations

a. Require a pilot to be designated as the PIC at all times.

b. Require the pilot to communicate to ensure safe operations.

c. Require the pilot to perform all procedures in accordance with applicable publications.

d. Require the pilot to perform all emergency procedures with accuracy and proficiency.

e. If equipped with a sensor operator workstation for any UAS, require at least one sensor operator in addition to one PIC.

f. Require the outgoing PIC to brief an incoming PIC prior to a transfer of control from within the same control station.

g. Require the outgoing PIC to brief an incoming PIC prior to a transfer of control between different CSs.

I. Control Station Handoff and Pilot Changeover during Operations

Initial Recommendations

a. Control station handoffs must be governed by the use of a checklist. As with manned platforms, positive transfer of control must be confirmed before the control station handoff is complete.

b. Pilot assuming control of the UAS has a complete understanding of all facets of the situation, including ATC clearance, any anomalies with the system, and other mission-relevant items deemed appropriate by the operating entity.

c. Control station handoff procedures will exercise concise communication protocols, conducted in a sterile environment, consistent with a critical phase of flight.

d. For crew changeovers, operating entities establish a standard changeover brief, to include at a minimum, UAS health and status, ATC clearances, any changes in mission requirements, and changes in normal aircraft configurations and standards (C-1 timer) or other areas deemed appropriate by the RPIC or operating entity.

J. Operations during Command and Control Degradation and Loss

Initial Recommendations

a. Additional information is required to make recommendations.

K. Operations during Periods of Limited Data from Aircraft relating to Attitude, Performance, or Environment

Initial Recommendations

a. If equipped, Pilot is able to use FMV during sensor degradation.

b. If equipped, the pilot must independently manage multiple telemetry datalinks.

c. Pilot must be able to plan for terrain masking that may inhibit the control station from receiving downlink telemetry.

d. Pilot must be capable of using multiple instruments to understand the aircraft's status.

e. Pilot must be able to prioritize most-to-least critical emergency procedures, shall multiple emergencies exist when operations during degraded sensory cues exists.

f. Pilot must be able to record the last known UA position, heading, airspeed, and calculate the proper heading and time required to navigate to a recovery point.

g. Pilot is required to consider winds at altitude to set a proper heading to return to normal operations.

h. If equipped with a directional ground data terminal (GDT), pilot is required to use GDT azimuth and dead reckoning icons to aid in navigation and maintain aircraft position.

i. Pilot must understand when conditions of partial or full loss of sensory cues exist.

L. Lost-Link Troubleshooting Procedures

Initial Recommendations

a. Pilot will be able to communicate with ATC upon encountering a lost-link; clearly communicate the outcome of troubleshooting and the actions taken as a result.

b. Pilot is required to be able to troubleshoot procedures to first address the possibility of re-establishing the command link.

c. Pilot is able to accurately predict the aircraft's initial preprogrammed action to going lost-link.

d. Pilot is able to accurately assess, when applicable, the time the aircraft shall arrive to a landing airfield, to include the flight path and altitude aircraft will transverse to destination and communicate to ATC those actions in order for traffic clearance.

e. Pilot once establishing link will be able to properly asses when the flight may be continued, or when the flight must be aborted.

M. Lost-Link Procedures (following confirmation of lost link)

Initial Recommendations

a. Require that the pilot be able to communicate lost link procedures to ATC.

b. Require the pilot to communicate last known UAS status to ATC (Altitude, heading, destination, lost-link flight plan, location, etc.) and expected response to lost link (i.e., rout of flight, orbit location, landing location, etc.).

c. Pilot is able to use troubleshooting method(s) available outside the control station (i.e. contacting off-site personnel) for the purpose of attempting to re-establish a lost link.

d. Pilot is able to accurately assess, when applicable, the time the aircraft shall arrive to a landing airfield, to include the flight path and altitude aircraft will transverse to destination and communicate to ATC those actions in order for traffic clearance.

N. In-Flight Emergencies

1. Propulsion failure – [In-Flight Emergencies]

Initial Recommendations:

a. Pilot shall quickly and accurately diagnose an engine/propulsion failure.

b. Pilot shall continue to maintain aircraft control and properly configure the aircraft for best glide ratio.

c. Pilot shall quickly determine glide distance.

d. Pilot shall select a suitable landing area, accurately assessing using risk management if landing to a runway or primary site can be completed without endangering personnel or property on the ground and in air.

e. Pilots shall assess possible air traffic at suitable landing area.

f. Pilot shall determine if no suitable landing airfield is available, the best area to make an off-field landing, ditch or terminate aircraft.

g. Pilot shall evaluate terrain and weather conditions en-route and at suitable landing area.

h. Pilot shall execute all applicable emergency checklists items per flight manual.

i. Pilot shall perform crew coordination actions.

j. Pilot shall ensure aircraft is squawking 7700.

k. Pilot shall communicate emergency to ATC while maintaining aircraft control.

l. When time permits, pilot will coordinate and communicate emergency with command center, ground support, and any other elements integrated into the make-up the unmanned system design.

2. Emergency descent – [In-Flight Emergencies]

Initial Recommendations

a. Pilot demonstrates the ability to assess priorities and execute proper division of attention.

b. Pilot shall utilize crew resource management and delegate when appropriate to other crewmembers to decrease task saturation.

c. Pilot must understand performance of the aircraft and how to correct when needed, to include any action points that may be triggered due to the state the aircraft is in.

d. Pilot will ensure aircraft is configured properly for emergency descent procedures.

e. Pilot will communicate with ATC to ensure all aviation traffic is cleared through the path of emergency descent.

f. Pilot will obtain current weather and ATIS information, to include obtaining and ensuring proper altimeter setting at landing area.

g. Pilot will execute all descent checklists and/or emergency descent checklists as time allows while maintaining aircraft control.

h. Pilot will brief and perform hand-off procedures to landing pilot and or shelter as applicable.

i. When time permits and aircraft control can be maintained, pilot will evaluate all options for alternate landing/termination points along descent and approach route in the event aircraft control cannot be maintained, runway or landing area can no longer be used due to safety of resources or lives or in the case of having to go missed approach.

3. Emergency landings – [In-Flight Emergencies]

Communication – Emergency landings – [In-Flight Emergencies]

Initial Recommendations

a. Pilot must be aware of and accurately communicate to ATC the emergency mission plan route and altitude aircraft is programmed to execute.

b. Pilot shall notify ATC as soon as possible when deviating from an ATC clearance, for safety of flight during an emergency landing.

c. Pilot shall limit communications to flight-critical information and emergency actions required during critical phases of flight.

d. Pilot must be prepared to provide ATC nature of emergency, fuel/time available, souls on board and intentions to include explanation of being a UAS and level of control/autonomy available to comply with ATC guidance.

e. During the transition portions and prior to landing, the pilot must have the knowledge and skills to communicate with the Launch and Recovery Element (LRE) if applicable.

f. Due to the current nature of UAS operations it may be necessary to create more detailed procedures with guidance for controlled and uncontrolled airspace and operations with specific step-by-step guidance on contact and clearance procedures for communication of UAS during an emergency.

Approach – Emergency landings – [In-Flight Emergencies]

Initial Recommendations

a. Pilot is able to determine and execute proper emergency, before landing, and approach checklist.

b. Pilot is able to monitor workstation and confirm proper airspeed, altitude, temperatures and performance parameters for approach.

c. Pilot is able to determine and verify proper landing location that will protect people and possible property from harm.

d. Pilot is able to identify minimum weather landing requirements for operations and confirms requirements are met.

e. Pilot can identify and seek waiver authority in the case of an emergency for landing below minimum weather or other stated requirements.

f. Pilot will ensure if unable to comply with the missed approach routing or climb requirements, coordination for alternate climb out instructions are made which ensures obstacle clearance.

g. For an engine out emergency, pilot will identify safest ditching/termination point if a safe landing can't be made while on the approach, or when directed to abort landing/go-around by ATC due to safety of life or resources.

h. For UAS's that are more autonomous and fly using GPS guidance from approach to landing, a previously developed arrival and/or departure procedure with emergency approach methods included, is required.

Touchdown – Emergency landings – [In-Flight Emergencies]

Initial Recommendations

a. Exhibits satisfactory knowledge of the elements related to an approach and landing to include any additional emergency procedures.

b. Executes all appropriate emergency and landing checklists.

c. Properly communicates with ATC to obtain proper landing clearance.

d. Properly communicates with visual observer, when applicable, to ensure cleared approach path, landing surface, and departure path in the case of a go-around.

e. Ensures aircraft is properly configured for landing, to include landing lights on and gear down.

f. Pilot is aware of minimum missed approach requirements and is able to properly execute a missed approach. Where standards or requirements are absent, establish standards.

g. Standards for UAS emergency landing procedures be developed for each variant of landing, size, and category that may be used as a standard that can be customized to each platform where such standards are absent.

Ditching site selection – Emergency landings – [In-Flight Emergencies]

Initial Recommendations

a. Pilot is able to execute ditching checklist.

b. Pilot is able to determine a suitable ditching location that will not involve undue risk to personnel or property on the ground.

c. Pilot will communicate with ATC about intention to ditch and location in order to keep traffic clear and expedite emergency vehicles and personnel to the scene.

d. Where there is an absence of standards or emergency ditching checklist for UAS, procedures shall be developed for each variant of size and category that may be used as a standard to which is customizable to each platform.

Flight termination – Emergency landings – [In-Flight Emergencies]

Initial Recommendations

a. Pilot is able to execute termination checklist.

b. Depending on the level of automation built in the termination procedures, pilot is familiar and will monitor or execute all steps for the termination sequence.

c. Pilot is able to determine a suitable termination point, if not previously identified in the mission plan, which upon terminating will not involve undue risk to personnel or property on the ground.

d. If Pilot is unable to reach a designated termination point, the pilot will direct the unmanned aircraft to an unpopulated area and initiate flight termination.

e. Pilot will communicate with ATC about intention to terminate and location in order to keep traffic clear and expedite emergency vehicles and personnel to the scene.

f. Where there is an absent of standards or emergency termination checklist for UAS, procedures shall be developed for each variant of size and category that may be used as a standard to which is customizable to each platform.

4. Uncontrolled flight (where real time human pilot input, either manual or through automated systems, has no effect on the aircraft attitude or flight path.) – [In-Flight Emergencies]

Initial Recommendations

a. Pilot shall identify systems and equipment failures and/or physiological factors that could lead to or hinder recovery from uncontrolled flight.

b. Pilot shall be able to execute applicable checklist for control link or equipment failure.

c. Pilot shall identify environmental factors that may be contributing to the uncontrolled flight.

d. Pilot will contact ATC to declare an emergency to allow coordination for aircraft deconfliction.

e. Development of more standardized procedures across all UAS for aircraft where real time human pilot input, either manual or through automated systems, has no effect on the aircraft attitude or flight path.

5. Navigation (GPS or other navigation system) failure – [In-Flight Emergencies]

Initial Recommendations:

a. Pilot shall understand the related systems to detect abnormal or possible emergency navigation situations.

b. Pilot shall correctly diagnose failures and takes timely action to trouble shoot navigation failures.

c. Pilot shall take appropriate action per checklists to recover aircraft using all internal and external references, to include engineers and communication specialists, and external controls from other shelters when available.

d. Pilot, when available, shall contact maintenance shelter and communication personnel to help troubleshoot navigation failure.

e. Pilot shall execute all proper checklists and prepare for emergency landing if system can land without internal navigation inputs.

f. Pilot will inform all applicable agencies, to include ATC, when aircraft cannot land without internal navigation. Pilot will provide information on predictive aircraft flight path to ATC so they can deconflict other traffic.

Development of more standardized procedures across all UAS for aircraft where navigation system failure hinders the ability to get to landing airfield or land at all.

APPENDIX C—OPERATIONAL PROCEDURES MATRIX

Procedure ID (OP#)	Procedure Name	Flight Card 1	Flight Card 2	Flight Card 3	Flight Card 4	Flight Card 5	Flight Card 6	Flight Card 7	Flight Card 8	Flight Card 9	Flight Card 10	Flight Card 11	Flight Card 12	Flight Card 13
1	Before Entering GCS	X												
2	Presets	X												
3	Pre-Flight		X											
4	Engine Start		X											
5	Pre-Taxi		X											
6	Taxi - General		X											
7	Taxi - Communications		X											
8	Pre-Takeoff Checks			X	X									
9	Takeoff Communications			X	X									
10	Takeoff Run/ Launch			X	X									
11	Initial Climb Out			X										
12	Aborted Takeoff				X									
13	Climb to Altitude - General					X								
14a	En-route Operations - General					X		X					X	
14b	En-route Operations - Navigation					X		X					X	
15	En-route Operations - Climb					X								
16	En-route Operations - Course Change					X								
17	En-route Operations - Descents					X				X				
18	Cruise Power Settings					X			X				X	
19	Weather Monitoring					X							X	
20	Descent From Cruise - General									X	X			
21	Approach - General									X	X			
22	Landing - Communications									X				
23	Approach and Landing - (Human in the Loop)									X				
24	Go Arounds									X	X			
25	Ground Support									X	X			
26	Approach and Landing (Automated)										X			
27	Post-Landing - Communications											X		
28	Post-Landing - Taxi											X		
29	Post-Landing - Ground Support											X		
30	Control Station Handoff - General												X	
31	Lost-Link Control Procedures - General					X								
32	Lost-Link Troubleshooting Procedures - General					X								
33	Operations During Command and Control Degradation and Loss - General						X							
34	Operations During Periods of Decreased Sensory Cues from Aircraft and Environment						X							
35	In-Flight Emergencies - Propulsion Failure						X							
36	In-Flight Emergencies - Two-way Communications Failure							X						
37	In-Flight Emergencies - Navigation Failure - GPS or Other System							X						
38	In-Flight Emergencies - Detect and Avoid													X
39	In-Flight Emergencies -Uncontrolled Flight							X						
40	In-Flight Emergencies - Emergency Descent								X					
41	Emergency Landing - Communication								X					
42	Emergency Landing - Approach								X					
43	Emergency Landing - Touchdown								X					
44	Emergency Landing - Ditching Site Selection						X							
45	Emergency Landing - Flight Termination						X	X						
46	Abnormal Operating Procedures - General													X

APPENDIX D—FLIGHT TEST CARDS WITH OBSERVED RESULTS

Flight Card Description	Flight Test #1	**Test Case Description**	Perform Pre-Entering GCS & Presets Operational Procedures			
Validation Attempt ID	All	**Data Collector ID**	Collective	**UAS Operator ID**	All	
Researcher/Assessor's ID	All	**Date Tested**	June 6, 2017	**Test Case (Pass/Fail)**	N/A	

Assumption	**Assumptions:**
1	UGCS operating in simulation mode
2	Platform Specific POH is Available
3	
4	

OP #	**Operational Procedures Validated**
2	Presets

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
2-1	Review CS maintenance logs.	The CS displays maintenance logbook information to the pilot.	Pass	Checked logbook.	Pass		Pass		Pass		Pass
2-2	Resolve open discrepancies, as required.	The CS displays open discrepancies for the pilot to determine if maintenance actions are required of the UA and CS.	Pass	Used an electronic logbook to determine faults.	Pass		Pass		Pass		Pass
2-3	Inspect control station.	The pilot detects any deficiencies with the CS prior to preflight.	Pass	Performed during the Preventative Maintenance Daily inspection.	Pass		Pass		Pass	With limits of Simulation	Pass
2-4	Conduct an inventory of all appropriate publications to include but not limited to: - Pilot Operating Handbook (POH) - Checklists - Regulations - Standard Operating Procedures (SOPs) - Aircraft weight and balance if required - Ensure all FAA publications are current - Ensure full FAA chart	The CS provides the pilot a reference for applicable publications prior to starting the preflight inspection, including: - Pilot Operating Handbook (POH) - Checklists - Regulations - Standard Operating Procedures (SOPs) - Aircraft weight and balance if required - Ensure all FAA	Pass	Pilot had Technical Manual (POH), Checklist, Airworthiness release, weight & balance sheets, weather forecast, and electronic charts loaded.	Pass	Military operations use standardized publications with same information	Pass		Pass		Pass

	coverage for the route	publications are current - Ensure full FAA chart coverage for the route									
2-5	Apply power to all required ground control equipment.	The pilot powers up all CS-related equipment necessary for flight.	Pass	Performed during the Preventative Maintenance Daily inspection.	Pass		Pass		Pass		Pass
2-6	Verify that the control station and aircraft powered up correctly in accordance with the applicable POH.	Pilot determines if the CS powered up correctly.	Pass	Performed during the Preventative Maintenance Daily inspection.	Pass		Pass		Pass	Software (Pass); Hardware (NE)	Pass
2-7	Ensure sufficient CS power is available for entire duration of operations.	Pilot determines if the CS has enough power throughout the flight, including generator fuel if powered by a generator or uninterruptable backup if powered from a non-generator source.	Not Observed	Only shore power was available.	Not Observed		Not Performed		Not Performed		NA (simulator)
2-8	Ensure functionality of all equipment as required.	Pilot verifies the CS hardware and software is set to the correct UA configuration.	Pass	Performed during power up.	Pass		Not Performed		Not Performed		Pass
2-9	Load and verify all maps and navigation data that are required for flight.	Pilot loads applicable map data, elevation data, and overlays.	Pass	Loaded and checked during presets.	Pass		Pass		Pass		Pass
2-10	Create, upload, and set mission plans.	Pilot creates, uploads, and sets a mission plan to the UA.	Pass	Used Aviation Mission Planning System (AMPS) on pilot workstation.	Pass		Pass		Pass		Pass
2-11	Ensure that all command and control link equipment, both in the control station and onboard the aircraft is correctly configured for flight.	Pilot sets control link equipment in CS and UA by establishing link and verifying control.	Pass	Recalled link profile. Set. Performed datalink terminal calibration. Set datalink terminal GPS location.	Pass		Pass		Pass		Pass
2-12	Tune all voice communication radios to the appropriate frequencies.	The pilot sets applicable voice communication frequencies and performs a radio check.	Pass	Simulated setting radio frequencies using the radio head unit.	Pass		Pass		Pass		Pass
2-13	Verify that all required approach plates, en-route charts, and any required supplements are in the control stations and accessible.	Pilot references applicable approach plates, en-route charts, and supplemental data within the control station.	Pass	Available prior to flight. Charts were loaded during preflight. Approach Charts were not used.	Pass		Pass		Pass		Pass

Flight Card Description	Flight Test #2	**Test Case Description**	Perform Preflight, Engine Start, Pre-Taxi, Taxi, and Communications Operational Procedures		
Validation Attempt ID	All	**Data Collector ID**	Collective	**UAS Operator ID**	All
Researcher/Assessor's ID	All	**Date Tested**	June 6, 2017	**Test Case (Pass/Fail)**	N/A

Assumption #	**Assumptions:**
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
3	Presets have been completed
4	Simulated ground clearance to taxi provided

OP #	**Operational Procedures Validated**
3	Preflight
4	Engine Start
5	Pre-Taxi
6	Taxi - General
7	Taxi - Communications

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
3-1	Verify successful completion of any BIT.	CS displays the result of a BIT test.	Pass	Displayed BIT status.	Pass	Multiple BITs to check	Pass	Met or exceeded expected results	Pass	Auto	Pass
3-2	Verify the correct function of the throttle control(s) as applicable.	The pilot uses the CS to manipulate the UA's throttle position and verify functionality prior to engine start.	Pass	Verified ignition switch as cold. Checked ECM.	Pass		Pass	Met or exceeded expected results	Pass		Pass
3-2-1	Set throttle to max	The pilot uses the CS to manipulate the UA's throttle position to maximum and verify correct UA response.	Pass	Displayed BIT status as pass.	Pass	Co-operative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-2-2	Set throttle to min	The pilot uses the CS to manipulate the UA's throttle position to minimum and verify correct UA response.	Pass	Displayed BIT status as pass.	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-3	Set/verify altimeter.	The pilot loads an altimeter setting of 30.09" Hg. The pilot should be able to determine is the CS commanded this altimeter setting to the UA.	Pass	Altimeter loaded. Value reported in GUI.	Pass	Adjust to current altimeter setting; "General Data"	Pass	Met or exceeded expected results	Pass		Pass

3-4	Perform IMU function checks.	The pilot performs an IMU built-in test. The CS displays the corresponding position change.	Pass	Checked in avionics status panel. BIT reported as pass.	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass	Not BIT check but physically moving UA with RPIC validation	Pass
3-5	Perform payload function checks, if applicable.	The pilot performs a payload check to slew the camera 360 degrees around, 90 degrees down, and nose position. The CS is able to display these payload functions to the pilot.	Pass	Nose camera video configured and checked. Mission payload camera not used.	Pass	No payload operator present	Not Observed	Met or exceeded expected results	Pass		Pass
3-6	Perform a function check on all redundant command link systems. Ensure that all systems function and are able to do so at the levels required for flight.	Pilot verifies functionality of all command datalinks prior to flight.	Pass	Link loss setting set. Set datalink terminal pointing direction.	Pass		Pass	Met or exceeded expected results	Pass		Pass
3-6-1	Pilot disables backup control link.	Pilot disables backup datalink and verifies the downlink telemetry datalink from primary link within the CS. Pilot determines a secondary uplink loss condition.	Pass	Selected receive only. Verified link warnings and primary control.	Pass		Pass	Met or exceeded expected results	Pass	And antenna configuration	Pass
3-6-2	Pilot disables primary control link.	Pilot disables primary datalink and verifies the downlink telemetry datalink from secondary link within the CS. Pilot determines a primary uplink loss condition.	Pass	Not performed.	Not Observed.	Disabled primary link - Redundant link takes over	Pass	Met or exceeded expected results	Pass		Pass
3-6-3	Pilot disables primary and secondary uplink control links.	Pilot disables both primary and secondary uplinks. Pilot determines the UA initiates link loss emergency mode.	Pass	Selected the SYS1 switch to off, disabling both datalinks.	Pass	Test by placing both links in Rx Only; re-established links	Pass	Met or exceeded expected results	Pass		Pass
3-7	Verify correct function of two-way communication radios by performing a radio check with a controlling agency, crew, or visual observer as required.	Pilot performs a two-way radio communications check with ATC, air/ground crew, and any Visual Observers.	Pass	Simulated setting the radio frequencies in the head unit, which was not functional in the simulator.	Pass		Pass	Met or exceeded expected results	Pass		Pass
3-8	Verify flight controls and flight control surfaces are free and correct.	Pilot deflects all flight control surfaces and receives confirmation of	Pass	Flight surfaces checked. Correct	Pass		Pass	Met or exceeded expected	Pass		Pass

		correct surface deflection.		response reported from crew chief (simulated).				results			
3-8-1	Set right roll.	Pilot determines if the right aileron deflects up and the left aileron deflects down.	Pass	Flight surfaces checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-2	Set left roll.	Pilot determines if the left aileron deflects up and the right aileron deflects down.	Pass	Flight surfaces checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-3	Set flaps down.	Pilot determines if the flaps deflect down.	Pass	Flight surfaces checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-4	Set flaps up.	Pilot determines if the flaps retract back up.	Pass	Flight surfaces checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-5	Set pitch down.	Pilot determines if the elevator/ ruddervator deflects down.	Pass	Flight surfaces checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-6	Set pitch up.	Pilot determines if the elevator/ ruddervator deflects up.	Pass	Flight surfaces checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-7	Set right yaw.	Pilot determines if the rudder/ ruddervator deflects right.	Pass	Flight surfaces checked. Correct	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected	Pass		Pass

				response reported from crew chief (simulated).				results			
3-8-8	Set left yaw.	Pilot determines if the rudder/ ruddervator deflects left.	Pass	Flight surfaces checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-9	Set nose wheel left.	Pilot determines if the nose wheel deflects left.	Pass	Nosewheel left checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-8-10	Set nose wheel right.	Pilot determines if the nose wheel deflects right.	Pass	Nosewheel right checked. Correct response reported from crew chief (simulated).	Pass	Cooperative task with crew chief	Pass	Met or exceeded expected results	Pass		Pass
3-9R	RECOMMENDED: Verify any inoperative items found on MEL during Pre-flight have been cleared and signed off.	Pilot determines MEL requirements and verifies if any inoperative items are on this list.	Pass	Any BIT failure equated to a NOGO for flight situation.	Pass		Fail	Met or exceeded expected results	Pass	No MEL for type series	Fail
3-9R-1	Verify navigation lights are functioning properly	Pilot turns on and off the navigation lights.	Pass	Navigation lights checked. Correct response reported from crew chief (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
3-9R-2	Verify anti-collision lights are functioning properly	Pilot turns on and off the anti-collision lights.	Pass	Anti-collision lights checked. Correct response reported from crew chief (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
3-9R-3	Verify landing lights are functioning properly	Pilot turns on and off the landing lights.	N/A	Not performed.	Not Observed.	Not equipped with landing light(s)	Fail	Met or exceeded expected results	Pass		N/A
3-9R-4	Verify fuel level.	Pilot verifies the CS is	Pass	Entered the fuel	Pass	Fuel is based	Pass	Met or	Pass	Manually enter	Pass

		displaying the correct amount of fuel onboard the UA.		level in GUI menu. Displayed fuel level in aircraft status panel.		upon a calculated consumption		exceeded expected results		fuel quantity provided by crew chief. Level displayed is based on this initial value and then burn rate.	
3-9R-5	Verify GPS functionality	Pilot verifies the CS is displaying the correct GPS health, status, and position.	Pass	Verified GPS positioning vis datalink terminal antenna pointing.	Pass	Verified in CS interface	Pass	Met or exceeded expected results	Pass		Pass
4-1	Coordinate with crew/applicable personnel to ensure that required safety equipment is present and that the area is clear of hazards and non-essential personnel.	Pilot determines if required safety equipment is present. Pilot verifies the area around the UA is clear of hazards and non-essential personnel.	Pass	Coordinated with crew chief via radio communications (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-2	Establish communication with appropriate ground control agency and ground crew to coordinate engine start procedure, if required.	Pilot communicates via CS-installed radios.	Pass	Coordinated with crew chief via radio communications (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-2-1	Set radio frequency to Redstone ATIS of 121.25MHz. Obtain current altimeter.	Pilot sets the radio to 121.25 MHz and obtains current altimeter setting.	Pass	Simulated setting the radio frequencies in the head unit, which was not functional in the simulator.	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-2-2	Set radio frequency to Redstone Ground of 124.8MHz and perform radio check.	Pilot sets radio to 124.8MHz and performs a radio check.	Pass	Simulated setting the radio frequencies in the head unit, which was not functional in the simulator.	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-2-3	Set radio frequency to an Internal Discrete of 126.20MHz and perform radio check.	Pilot sets radio to 126.20MHz and performs a radio check with ground crew.	Pass	Simulated setting the radio frequencies in the head unit, which was not functional in the simulator.	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-3	Ensure that the system is properly configured for	Pilot sets UA systems for engine start.	Pass	Checked the engine status	Pass		Pass	Met or exceeded	Pass		Pass

	engine start and begin engine start procedures.			panel as set to cold.				expected results			
4-3-1	Set throttle for engine start.	Pilot sets the throttle for engine start.	Pass	Set to idle.	Pass	Set within CS interface via slider	Pass	Met or exceeded expected results	Pass	Auto	Pass
4-3-2	Set ignition switch for engine start.	Pilot ensures the UA's ignition switch is set for engine start.	Pass	Enabled engine start switch from cold to hot from within CS. Coordinated with crew chief to select UA ignition switch to hot (simulated).	Pass	Crew chief toggles the ignition switch	Pass	Met or exceeded expected results	Pass	Crew Chief does this on actual aircraft based on the RPIC direction.	Pass
4-3-3	Verify glowplug status (if equipped)	Pilot determines if glowplug (if equipped) is ready for engine start.	Pass	Checked in the engine status panel.	Pass		N/A	Met or exceeded expected results	Pass		N/A
4-3-4	Start engine	Pilot starts engine from CS.	Pass	Coordinated with crew chief to select UA starter switch to start (simulated).	Pass	Crew chief starts when commanded by PIC	Pass	Met or exceeded expected results	Pass	Crew Chief does this based on RPIC direction	Pass
4-4	Monitor engine health throughout the engine start procedure.	Pilot monitors engine instrumentation during engine start.	Pass	Checked engine health status. Ready to select engine kill if limitations were exceeded or engine fire started.	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-4-1	Monitor oil pressure.	Pilot acknowledges the oil pressure is within prescribed limitations.	Pass	Checked the oil pressure was within spec.	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-4-2	Monitor fuel pressure.	Pilot acknowledges the fuel pressure is within prescribed limitations.	Pass	Checked the fuel rail pressure was within spec.	Pass		Pass	Met or exceeded expected results	Pass		Pass
4-4-3	Monitor coolant temperature.	Pilot acknowledges the coolant temperature is within prescribed limitations.	Pass	Checked the coolant temperature was within spec.	Pass	The aircraft powerplant is air cooled	N/A	Met or exceeded expected results	Pass		N/A
4-4-4	Monitor RPM.	Pilot acknowledges the engine RPM is within prescribed limitations.	Pass	Checked the engine RPM was within spec.	Pass	Pilot monitors RPM	Pass	Met or exceeded expected	Pass		Pass

								results			
4-4-5	Monitor manifold pressure.	Pilot acknowledges the manifold pressure is within prescribed limitations.	Pass	Checked the manifold pressure was within spec.	Pass	Aircraft has a fixed-pitch propeller	N/A	Met or exceeded expected results	Pass		N/A
4-4-6	Set warmup RPM	Pilot sets the correct engine RPM for warmup.	Pass	Checked that RPM remained at idle for warmup.	Pass	Set an RPM of 4500 for warmup	Pass	Met or exceeded expected results	Pass	Auto button sequence	Pass
4-4-7	Monitor EGT temperature	Pilot acknowledges the EGT temperature is within prescribed limitations.	Pass	Checked the EGT was within spec.	Pass	Look for popup indications; no indication if nominal	Pass	Met or exceeded expected results	Pass		Pass
4-4-8	Monitor output current	Pilot acknowledges the output current is within prescribed limitations.	Pass	Checked total system amps in engine status monitor.	Pass	Not equipped to read output current	N/A	Met or exceeded expected results	Pass	Not available in system	N/A
4-5	Verify proper operation of the engine and all engine instrumentation.	Pilot verifies the engine instrumentation is within required specifications.	Pass	Checked engine operation.	Pass	Run "snaps" and observe indications	Pass	Met or exceeded expected results	Pass		Pass
4-5-1	Perform alternator check	Pilot determines if the alternator is working correctly.	Pass	Checked alternator A, then both, then alternator B, then both. Checked output amps.	Pass		N/A	Met or exceeded expected results	Pass		N/A
4-5-2	Perform bus voltage check	Pilot determines if the bus voltage is within the specified range.	Pass	Checked bus voltage.	Pass	Directly monitor bus voltage indication	Pass	Met or exceeded expected results	Pass		Pass
4-6	Perform abnormal engine start procedures, if required.	Pilot performs abnormal engine starting procedures from the CS.	Pass	There were no abnormal engine starting procedures.	Not Applicable.		Not Observed	Met or exceeded expected results	Pass		N/A
4-6-1	Perform cold temperature engine start procedures	The pilot performs a cold engine starting procedure from the CS.	As applicable	There were no cold engine starting procedures.	Not Applicable.		Not Observed	Met or exceeded expected results	Not Performed		N/A
4-7	In the event of an emergency during engine start, perform an emergency engine shutdown.	Pilot shuts down the engine.	Pass	Not required, but showed two methods to shut down the engine in the CS.	Pass		Not Observed	Met or exceeded expected results	Pass	Ignition switch on aircraft (Crew Chief) command stop from CS	Pass
5-1	Verify UA free of frost	Pilot determines if pitot	Pass	Checked icing	Pass		Not observed	Met or	Pass		N/E

	and/or ice.	heat/ pitot anti-icing system is functional.		detector by coordinating with crew chief to hand hold the icing detector to reduce vibrations, causing the detector to indicate icing.				exceeded expected results			
5-2	Contact ATC and request taxi clearance/instructions (if applicable). If at a non-towered airport, communicate with other traffic on common traffic advisory frequency (CTAF) and/or utilize visual observers or other available means to ensure separation from traffic during taxi.	Pilot performs two-way communication with ATC to request taxi clearance.	Pass	Performed (simulated).	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
5-3	Check all critical instrumentation for correct settings including but not limited to altimeter, navigation equipment, radios, etc.	Pilot monitors instruments prior to taxi	Pass	Checked FCAs in auto. Checked FADEC A/B health.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
5-3-1	Check flight mode commands	Pilot verifies the flight mode commands prior to taxi.	Pass	Performed.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
5-3-2	Check altimeter setting	Pilot verifies the current altimeter setting is loaded.	Pass	Checked ALT-GPS, ALT-MSL, ALT-Laser. Compared difference to meeting prescribed specs.	Pass		Pass	Met or exceeded expected results	Pass		Pass
5-3-3	Check GPS equipment	Pilot verifies the health, status, and position from the GPS.	Pass	Continuously monitored.	Pass		Pass	Met or exceeded expected results	Pass	Auto	Pass
5-4	Ensure all flight displays are correctly set and configured for flight.	Pilot sets the correct GUI displays for taxi	Pass	Pulled up applicable menu.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected	Pass	No Taxi	N/A

								results			
5-4-1	Set attitude indicator GUI	Pilot sets attitude indicator GUI for taxi	Pass	Checked.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
5-4-2	Set airspeed indicator GUI	Pilot sets airspeed indicator GUI for taxi	Pass	Checked.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
5-4-3	Set altitude indicator GUI	Pilot sets altitude indicator GUI for taxi	Pass	Checked.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results		No Taxi	N/A
5-4-4	Set UA location on location display	Pilot sets and locates the UA's position on the location display.	Pass	Checked FCA1, 2, 3 and GPS health.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	Auto	Pass
5-5	Brief any participating crewmembers on the following: - Taxi route - Known hazards along the route - Contingencies to address any abnormal or emergency situations	Pilot communicates with ground crew to perform a pre-taxi briefing, to include: - Taxi route - Known hazards along the route - Contingencies to address any abnormal or emergency situations	Pass	Performed.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-1	Verify that command and control data links have the required signal strength and reliability required for taxi.	Pilot verifies command and control data links have the required signal strength and reliability required for taxi from within the CS.	Pass	Performed.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-2	If brakes are installed, perform a check of brake function to ensure the UAS may be stopped at any point during taxi. Utilize ground crew to verify brake function, if applicable.	Pilot performs a brake check by coming to a complete stop within one length of the UA.	Pass	Performed by pulling joystick rearward.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Brakes on this type aircraft.	N/A
6-3	If link loss during taxi, contact ground control element, if applicable.	The pilot detects the UA has stopped during an uplink loss failure.	Pass	Set taxi brake duration for link loss.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-4	Utilize visual aids and markers to assist with taxi operations to the maximum extent possible.	The pilot uses cameras onboard the UA to properly recognize airport surface signage.	Pass	Performed.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-5	If possible, maintain ~~visual~~	The pilot maintains	Pass	Marshaller not	Not	Aircraft is not	N/A	Met or	Pass	No Taxi	N/A

	contact and/or two-way radio communication with a marshaller, if one is used.	contact with a marshaller.		used.	observed.	taxied		exceeded expected results			
6-5-1	Maintain ~~visual~~ contact with a marshaller, if one is used.	The pilot uses an onboard camera to maintain visual contact with a marshaller.	Pass	Marshaller not used.	Not observed.	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-5-2	Maintain two-way ~~radio~~ contact with a marshaller, if one is used.	The pilot uses two-way radio contact from within the CS to maintain contact with a marshaller.	Pass	Marshaller not used.	Not observed.	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-6	Conduct taxi operations at the pace of the marshaller, or vehicle observer.	Pilot taxis at the same speed as the marshaller.	Pass	Marshaller not used.	Not observed.	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-7	When using full-motion video, stop UA if taxiway centerline is lost and contact cannot be regained in a reasonable amount of time.	Pilot stops the UA if the runway centerline is lost.	Pass	Performed.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-8	Set taxi speed such that the UAS is able to be brought to a stop within a safe distance of obstacles and other traffic.	Pilot maintains a taxi speed to enable a full-stop to avoid obstacles.	Pass	Used speed indicator in HUD.	Pass	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
6-9	Maintain communication with ground control and/or applicable ground crew throughout taxi.	The pilot uses two-way radio contact from within the CS to maintain contact with a marshaller.	Pass	Marshaller not used.	Not observed.	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
7-1	Maintain sterile cockpit while taxiing.	Pilot maintains a sterile cockpit within the CS.	Pass	Not required.	Not applicable.	Aircraft is not taxied	N/A	Met or exceeded expected results	Pass	No Taxi	N/A
7-2	Use backup communications during primary communications failure.	Pilot selects backup communications methods if the voice radio communications method fails	Pass	Used a secondary radio from CSC selector.	Pass	Pilot is capable of using a phone or passing messages to crew verbally	Pass	Met or exceeded expected results	Pass		Pass

Flight Card Description	Flight Test #3	Test Case Description	Perform Pre-Takeoff Checks, Takeoff Communications, Takeoff Run/ Launch, and Initial Climb Out Operational Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All
Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
4	Simulated ground clearance to taxi provided
5	UA taxied to departure runway. Cleared to position and hold on active runway
6	AIM is available in CS

OP #	Operational Procedures Validated
8	Pre-Takeoff Checks
9	Takeoff Communications
10	Takeoff Run/ Launch
11	Initial Climb Out

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
8-1	Complete any remaining pre-takeoff checks prior to taking position on the runway.	Pilot completes takeoff check within CS prior to taking the active runway.	Pass	Checked FCA 1, 2, 3, and GPS health.	Pass	Preflight is completed prior to placing the aircraft on the launcher	Pass	Met or exceeded expected results	Pass	Launcher not Runway	Pass
9-1	Obtain ATC clearance in accordance with procedures in AIM Section 4.	Pilot performs two-way radio communications with ATC for takeoff clearance.	Pass	Performed (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
9-2	Record clearances in accordance with AIM 4-4-7a.	Pilot records ATC takeoff clearance.	Pass	Performed (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
9-3	Use backup communications during primary communications failure.	Pilot uses a backup method of communications with ATC in the event of a two-way radio communications failure.	Pass	Performed (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
10-1	Perform flight checks of any critical systems. Verify proper setting and strength of required command	Pilot verifies the datalinks are working correctly.	Pass	Checked. Turned output power to 100%.	Pass		Pass	Met or exceeded expected results	Pass	Datalink failure is a WCA (auto detect)	Pass

	link(s).										
10-2	Verify traffic is clear.	Pilot identifies the presence of potential traffic conflicts.	Pass	Used nose camera and ATC clearance.	Pass		Pass	Met or exceeded expected results	Pass		Pass
10-3	Acknowledge receipt of clearance using standard phraseology and read-back practices.	Pilot performs two-way radio communications from within the CS to provide a read-back of ATC clearance instructions.	Pass	Performed (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
10-4	Maintain runway centerline; maintain runway heading at rotation.	Pilot is able to taxi the UA onto the runway centerline and maintain centerline until rotation.	Pass	Monitored nose camera video.	Pass		N/A	Met or exceeded expected results	Pass		N/A
10-5	Maintain takeoff power and monitor critical power plant operating parameters.	Pilot maintains the proper takeoff power setting from within the CS while simultaneously monitoring engine health.	Pass	Monitored RPM, manifold pressure, IAS.	Pass		Pass	Met or exceeded expected results	Pass		Pass
10-6	Ø Monitor flight-critical systems, including by not limited to: - Navigation system, - Two-way communications, - Detect, sense and avoid equipment, as applicable - Command and control link, and - Any other flight-critical systems/equipment.	Pilot monitors and acknowledges the function of flight critical systems from within the CS including: - Navigation system - Two-way communications - Command and control link - Any other flight-critical systems/equipment	Pass		Pass	Most alerts populate as needed in warning/caution/alert window	Pass	Met or exceeded expected results	Pass		Pass
10-7	Consider takeoff abort if required if an emergency situation develops.	Pilot determines takeoff abort parameters during the takeoff procedure.	Pass		Pass	Acknowledges system cues and aborts if required	Pass	Met or exceeded expected results	Pass		Pass
11-1	Rotate at rotation speed (V_R or V_{ROT}).	The pilot determines V_R or V_{ROT} and rotate at that airspeed.	Pass		Pass		N/A	Met or exceeded expected results	Pass		N/A
11-2	Maintain appropriate V speed during climb out.	Pilot maintains V_y or V_x after rotation.	Pass		Pass	Climb @ 55 kts (Automated)	Pass	Met or exceeded expected results	Pass		Pass
11-3	Maintain ATC-instructed departure altitudes and headings, as applicable.	Pilot maintains the ATC-instructed heading, altitude, and airspeed.	Pass		Pass		Pass	Met or exceeded expected results	Pass		Pass

Flight Card Description	Flight Test #4	Test Case Description	Perform Pre-Takeoff Checks, Takeoff Communications, Takeoff Run/ Launch, and Aborted Takeoff Operational Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All
Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
4	Simulated ground clearance to taxi provided
5	UA taxied to departure runway. Cleared to position and hold on active runway
6	AIM is available in CS

OP #	Operational Procedures Validated
8	Pre-Takeoff Checks
9	Takeoff Communications
10	Takeoff Run/ Launch
12	Aborted Takeoff

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	Operational Procedure/ Process Step	Expected Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended
8-1	Complete any remaining pre-takeoff checks prior to taking position on the runway.	Pilot completes takeoff check within CS prior to taking the active runway.	Pass		Pass	Completed this task in earlier flight test card; runway element not applicable	N/A	Met or exceeded expected results	Pass	Launcher vice runway	N/A
9-1	Obtain ATC clearance in accordance with procedures in AIM Section 4.	Pilot performs two-way radio communications with ATC for takeoff clearance.	Pass	Performed (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass
9-2	Record clearances in accordance with AIM 4-4-7a.	Pilot documents ATC takeoff clearance.	Pass	Performed (simulated).	Pass	For military ops, clearances are logged in official forms.	Pass	Met or exceeded expected results	Pass		Pass
9-3	Use backup communications during primary communications failure.	Pilot uses a backup method of communications with ATC in the event of a two-way radio communications failure.	Pass	Not performed	Not Applicable		Pass	Met or exceeded expected results	Pass		Pass
10-1	Perform flight checks of any critical systems. Verify proper setting and strength of required command link(s).	Pilot verifies the datalinks are working correctly.	Pass		Pass		Pass	Met or exceeded expected results	Pass	WCA	Pass
10-2	Verify traffic is clear.	Pilot identifies the presence of potential traffic conflicts prior to taking the active runway.	Pass		Pass		Pass	Met or exceeded expected results	Pass	Launcher	Pass
10-3	Acknowledge receipt of clearance using standard	Pilot performs two-way radio communications from within	Pass		Pass		Pass	Met or exceeded expected results	Pass		Pass

	phraseology and read-back practices.	the CS to provide a read-back of ATC clearance instructions.									
10-4	Maintain runway centerline; maintain runway heading at rotation.	Pilot taxis the UA onto the runway centerline and maintain centerline until rotation.	Pass		Pass	The aircraft does not rotate due to utilizing a launcher for takeoff.	N/A	Met or exceeded expected results	Pass	Launcher	N/A
10-5	Maintain takeoff power and monitor critical power plant operating parameters.	Pilot monitors and acknowledges the function of takeoff power setting and engine health.	Pass		Pass	Pilot monitors aircraft in automated takeoff procedure	Pass	Met or exceeded expected results	Pass		Pass
10-6	Monitor flight-critical systems, including by not limited to: - Navigation system - Two-way communications - Command and control link - Any other flight-critical systems/equipment	Pilot monitors and acknowledges the function of flight critical systems from within the CS including: - Navigation system - Two-way communications - Command and control link - Any other flight-critical systems/equipment	Pass		Pass		Pass	Met or exceeded expected results	Pass		Pass
10-7	Consider takeoff abort if required if an emergency situation develops.	Pilot determines takeoff abort parameters during the takeoff procedure.	Pass		Pass		Pass	Met or exceeded expected results	Pass		Pass
12-1	Maintain an airspeed that allows positive control of the UAS.	Pilot is able to determine airspeed and rate-of-climb; and maintain an airspeed that allows a positive rate of climb.	Pass		Pass		Pass	Met or exceeded expected results	Pass	Auto until Knobs	Pass
12-2	Maintain heading clear of obstacles.	Pilot detects obstacles and maintain headings that are clear of obstacles.	Pass		Pass	Commands aircraft heading to remain clear	Pass	Met or exceeded expected results	Pass		Pass
12-3	Communicate the aborted takeoff to ATC as soon as practical.	Pilot performs two-way radio communications to inform ATC of an aborted takeoff condition.	Pass	Performed (simulated).	Pass		Pass	Met or exceeded expected results	Pass		Pass

Flight Card Description	Flight Test #5	Test Case Description	Perform Climb to Altitude, En-Route Operations, Cruise Power Settings, Weather Monitoring, Lost-Link Control Procedures, and Lost-Link Troubleshooting Procedures		
Validation Attempt ID	All	**Data Collector ID**	Collective	**UAS Operator ID**	All
Researcher/Assessor's ID	All	**Date Tested**	June 6, 2017	**Test Case (Pass/Fail)**	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
6	AIM is available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	Operational Procedures Validated
13	Climb to Altitude - General
14a	En-route Operations - General
14b	En-route Operations - Navigation
15	En-route Operations - Climb
16	En-route Operations - Course Change
17	En-route Operations - Descents
18	Cruise Power Settings
19	Weather Monitoring
31	Lost-Link Control Procedures - General
32	Lost-Link Troubleshooting Procedures - General

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
13-1	Maintain contact with ATC and perform frequency changes as requested.	Pilot changes ATC frequencies during flight.	Pass	Met or exceeded expected results	Pass	Changes Frequency; notional here	Pass	Met or exceeded expected results	Pass		Pass
13-1-1	Contact Huntsville Departure on 118.05MHz	Pilot changes the two-way radio to 118.05MHz.	Pass	Met or exceeded expected results	Pass	Changes Frequency; notional here	Pass	Met or exceeded expected results	Pass		Pass
13-2	Ensure that the aircraft is configured for climb.	Pilot uses CS to set UA for flight and command a climb.	Pass	Met or exceeded expected results	Pass	Commands and monitors climb	Pass	Met or exceeded expected results	Pass		Pass
13-2-1	Climb to 5,000 feet.	Pilot commands a climb to 5,000 feet MSL.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
13-3	Maintain heading assigned by ATC unless cleared to deviate or climb/maneuver at pilot's discretion.	Pilot turns and maintains a heading of 360 degrees magnetic.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
13-4	Level off at assigned altitude.	Pilot levels off at 5000 feet MSL.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14a-1	Use proper communication procedures when using radar services (as	The pilot uses two-way communication with ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass

	applicable).											
14a-1-1	Contact Memphis Center on 120.8MHz.	The pilot changes the two-way radio frequency to 120.8 while in flight and contact the Memphis ARTCC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-2	Obtain ATC clearance.	Pilot performs two-way radio communication to obtain an ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-2-1	Request clearance for transitioning into R-2104B	Pilot performs two-way radio communication to request clearance into R-2104B restricted airspace.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-3	Respond to ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-3-1	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot reads back the ATC clearance approval using standard aviation terminology.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-4	Comply with ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-4-1	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot turns the UA into R2104B, remain within that airspace, climb to 5,000 feet MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-5	Use standard aviation phraseology when communicating with ATC.	Pilot uses standard aviation phraseology when communicating with ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass			Pass
14a-6	Set communication frequencies, navigation systems, and transponder codes to ensure compliance with ATC clearances.	Pilot switches radio navigation frequencies and transponder code from within the CS.	Pass	Met or exceeded expected results	Pass	Changed transponder frequency	Pass	Met or exceeded expected results	Pass			Pass
14a-7	Conduct any required communication frequency changes.	Pilot switches two-way radio frequencies from within the CS.	Pass	Met or exceeded expected results	Pass	Pass		Met or exceeded expected results	Pass			Pass
14a-8	Use available systems (if equipped) to detect icing conditions.	Pilot uses the CS to detect icing.	Pass	Met or exceeded expected results	Pass	No system to detect ice	Not Observed	Met or exceeded expected results	Pass			Pass
14a-8-1	Determine if the pitot tube has ice.	Pilot uses the CS to detect icing on the pitot tube.	Pass	Met or exceeded expected results	Pass		Not Observed	Met or exceeded expected results	Pass			Pass
14a-8-2	Determine if the UA has structural ice.	Pilot uses the payload video to inspect the UA for structural icing.	Pass	Met or exceeded expected results	Pass		Not Observed	Met or exceeded expected results	Pass			Pass

14a-9	Monitor aircraft electrical, propulsion, and datalink performance.	Pilot monitors status and health of electrical, propulsion, and datalink systems.	Pass	Met or exceeded expected results	Pass	Pilot scans multiple windows	Pass	Met or exceeded expected results	Pass		Pass
14a-9-1	Determine if current bus voltage is within limitations.	Pilot monitors bus voltage and determine it is within the POH-required limits.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Auto and # display	Pass
14b-1	Monitor aircraft's position throughout the flight and maintain course in accordance with ATC instructions/clearance.	Pilot determines the location of the UA on a location display.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-1-1	Determine current location	Pilot determines current location on the location display and/ or GPS coordinate display.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-1-1	Turn and maintain 130 degrees.	Pilot turns from 360 degrees to 130 degrees.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-2	Intercept and track a given course, radial (if equipped), or bearing, as appropriate.	Pilot plots a course and command the UA heading.	Pass	Met or exceeded expected results	Pass	Not equipped to track radials	Fail	Met or exceeded expected results	Pass	GPS Pt to PT only. Pilot could calculate equivalent radial intercept with VOR position information.	N/A
14b-2-1	Determine the course heading to Nashville, TN.	Pilot plots a course heading from the UA's current position direct to Atlanta, GA. While factoring winds.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-2-2	Determine a ground track to Nashville, TN.	Pilot determines a ground track necessary for a direct course to Atlanta, GA.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-3	Determine loss of GPS or navigation solution if it occurs.	The pilot interprets the GPS health and status within the CS.	Pass	Met or exceeded expected results	Pass	Pilot observes indications to determine GPS health	Pass	Met or exceeded expected results	Pass	WCA with secondary menus display for more detail information	Pass
14b-4	Maintain the appropriate altitude and headings.	Pilot turns the UA and change altitude while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-4-1	Turn to heading 350 degrees.	Pilot turns the UA to 350 degrees magnetic.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-4-2	Climb and maintain 10,000	Pilot climbs the UA to	Pass	Met or exceeded expected	Pass		Pass	Met or exceeded	Pass	Used 5,000 ft	Pass

	feet MSL.	10,000 MSL and level off.		results				expected results			
14b-4-3	Perform dead reckoning navigation if required.	Pilot uses payload video to navigate back to a landing airport.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-4-4	Return to Huntsville International Airport via heading and airspeed.	Pilot uses the UA's heading and ground speed to return to HSV.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-4-6	Use payload video to enter the traffic pattern at Huntsville International Airport.	Pilot uses payload video to navigate into the traffic pattern.	Pass	Met or exceeded expected results	Not Observed.		Pass	Met or exceeded expected results	Pass		Pass
14b-6	Maintain course by reference to established waypoints/steer points or other navigational references, as applicable.	Pilot remains on an established course and changes course once waypoints are achieved.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-7	If equipped, be able to identify surface features to chart symbols.	Pilot performs map to video correlation between the payload video and location display to identify natural and man-made terrain features.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		N/E
14b-8	Navigate by means of precomputed headings, groundspeeds, and elapsed time (if required).	Pilot determines a required heading +/- 10 degrees, groundspeed +/- 10 knots, and time +/- 3 minutes.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Manual calculation from provided data	Pass
14b-9	Correct for wind to maintain desired route and performance.	The Pilot acknowledges and corrects for wind to maintain desired course.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-10	Remain within planned route described in the flight plan.	The Pilot commands the UA to maintain the desired course, speed, and altitude outlined in the flight plan.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-10-1	Obtain ATC clearance.	Pilot performs two-way radio communication to obtain an ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-10-2	Request clearance for transitioning into R-2104B	Pilot performs two-way radio communication to request clearance into R-2104B restricted airspace.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-10-3	Respond to ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-10-4	Cleared into R-2104B airspace. Maintain climb	Pilot reads back the ATC clearance approval using	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass

	and maintain 5,000 feet MSL.	standard aviation terminology.									
14b-10-5	Comply with ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
14b-10-6	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot turns the UA into R2104B, remain within that airspace, climb to 5,000 feet MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Used simulated airspace	Pass
15-1	Conduct en-route climbs according to ATC clearance.	Pilot complies with ATC altitude instructions.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
15-1-1	Climb and maintain 7,500 feet MSL.	Pilot climbs and maintains 7,500 feet MSL.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Used 5,000ft	Pass
15-2	Conduct climbs with respect to UAS performance limitations, including but limited to: - Absolute ceiling - service ceiling - altitude and temperature - time, fuel, and distance to climb	Pilot climbs to the UA's performance limits identified in the POH.	Pass	Met or exceeded expected results	Pass	Parameters considered in climb. Limitations are built into the system.	Pass	Met or exceeded expected results	Pass		Pass
15-2-1	Determine time to climb to service ceiling	Pilot determines the time required to climb from current altitude to the service ceiling. The pilot should plan within +/- 3 minutes.	Pass	Met or exceeded expected results	Pass	The pilot has a chart available to outline climb performance and correlate it with a rate of climb	Pass	Met or exceeded expected results	Pass		Pass
15-2-2	Perform a climb to service ceiling.	Pilot determines the UA's service ceiling from POH and command a climb. Pilot monitors the performance of the climb and determine when service ceiling is reached from the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
15-2-3	Perform a maximum airspeed dash.	Pilot determines the maximum airspeed and command the UA to maximum speed. Pilot monitors UA's performance at maximum speed from the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
15-3	Notify ATC if the UA is unable to climb at a specified rate or gradient in accordance with AIM 4-4-	If the pilot detects climb performance less than 500 feet per minute, the pilot notifies ATC to	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass

	10(d).	indicate unable to comply with ATC instructions.									
16-1	Obtain and/or acknowledge clearance to change course from ATC.	The pilot uses two-way radio communication and acknowledge ATC course change instructions.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
16-2	Command the UA to fly the desired heading or course.	The pilot maneuvers the UA by changing course heading according to ATC instructions within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
16-3	Verify the UA is flying the commanded heading and/or course using available flight data.	The pilot determines the commanded heading or course from within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
16-4	Make corrections to maintain heading and/or course as required.	The pilot detects deviations from the desired heading or course and adjusts commands to the UA to correct deviations from within the CS.	Pass	Met or exceeded expected results	Pass	The pilot may command desired courses and headings. They have the capability of flying specific ground tracks with a "ground track" tool; can feed in headings to be followed.	Pass	Met or exceeded expected results	Pass		Pass
17-1	Conduct descents in accordance with ATC clearance.	Pilot commands a descent of the UA when required by ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Used 3,000 ft	Pass
17-1	Descend and maintain 5,000 feet MSL.	Pilot commands a descent of the UA when required by ATC.	Pass	Met or exceeded expected results	Pass	Pilot descends to given altitude when commanded	Pass	Met or exceeded expected results	Pass		Pass
17-2	Conduct descents with regard to UAS limitations.	The pilot descends with a maximum descent rate less than the POH limitation.	Pass	Met or exceeded expected results	Pass	The system has established limits on descent rate	Pass	Met or exceeded expected results	Pass		Pass
17-3	Do not exceed UAS performance limitations in descents.	The pilot does not exceed airspeed, pitch, or roll in excess of the maximum limitation identified in the POH.	Pass	Met or exceeded expected results	Pass	The system has established limits on descent rate	Pass	Met or exceeded expected results	Pass		Pass
18-1	Monitor UA fuel/battery status while in flight.	Pilot determines the status of fuel/ battery during flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
18-1-1	Determine fuel burn rate.	The pilot determines the rate of fuel consumption from within the CS.	Pass	Met or exceeded expected results	Pass	Fuel burn rate is an embedded variable that is determined by	Pass	Met or exceeded expected results	Pass	Initial input and fuel burn but no direct level gauge	Pass

						charts and environmental parameters						
18-1-1	Determine fuel consumed.	The pilot determines the amount of fuel consumed within 10 gallons and how much remains within 10 gallons since engine start.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
18-1-2	Determine fuel remaining.	The pilot determines the amount of fuel remaining from within the CS since engine start.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
18-2	Adjust power settings as required to maintain desired performance.	The pilot sets the power setting for maximum range or endurance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Set indirectly by selecting airspeed, and /or altitude change commands	Pass
18-3	Perform fuel burn/battery life calculations such that the destination is reached with the required fuel/battery reserve remaining.	Pilot calculates fuel/ battery remaining requirements within 10 gallons or 5 minutes to complete a mission with reserve capacity from the CS while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
18-3-1	Determine the fuel required with a 30-minute reserve to fly to Memphis International Airport.	Pilot calculates the fuel requirements, taking into account GS, time, distance, fuel burn rate, and reserve from within the CS while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Manual calculation from provided data	Pass
18-4	Re-evaluate performance data as required to reach the destination at the required time with the required fuel/battery reserves.	Pilot re-evaluates performance/ endurance, including fuel/ battery reserves within 10 gallons or 5 minutes after a change in the mission plan.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
18-4-1	Climb to 10,000 feet	Pilot re-calculates the fuel requirements, taking into account GS, time, distance, fuel burn rate, and reserve within 10 gallons or 5 minutes.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	POH Table	Pass
18-5	Determine any new performance capabilities or limitations that may result from alterations in the flight plan or an in-flight	Pilot is able to determine if any performance limitations changed as a result of altering the flight plan form the CS while in	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass

	emergency.	flight.									
19-1	Monitor weather conditions along the route of flight, establishing communications with in-flight weather services as required.	Pilot monitors current and forecasted weather conditions for current location, route of flight, and destination form the CS while in flight.	Pass	Met or exceeded expected results	Pass	Pilot has to rely on outside help for this information; notional in this instance	Pass	Met or exceeded expected results	Pass		Pass
19-2	Determine if icing conditions exist and utilize anti/de-icing equipment as appropriate.	Pilot determines if icing conditions exist form the CS while in flight.	Pass	Met or exceeded expected results	Pass		Not Observed	Met or exceeded expected results	Pass	No Payload cameras.	N/E
19-3	When necessary, alter the flight plan to avoid weather that poses a hazard to the safety of flight.	Pilot maneuvers the mission plan to avoid hazardous weather to the destination from the CS while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
19-4	Notify ATC if a flight plan must be altered to avoid hazardous weather.	Pilot performs two-way radio communications to inform ATC of alterations to planned flight of route because of hazardous weather conditions.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
31-1	Ensure that lost-link fail safes are set up as appropriate for the flight (including any automated transponder triggering to squawk 7400) and active throughout all phases of flight.	Pilot determines the current lost-link/ contingency actions and transponder actions prior to a lost-link event occurring.	Pass	Met or exceeded expected results	Pass	The system does not automatically trigger a transponder code change upon initiating lost-link protocols.	Fail	Met or exceeded expected results	Pass	Does not change transponder to 7400	Fail
31-2	Communicate lost-link behavior to ATC and verify appropriate transponder squawk code, if able.	Pilot performs two-way radio communication if a lost link conditions exists. Pilot is able to verify transponder code.	Pass	Met or exceeded expected results	Pass	Note: Radio communications occur through the control station	Pass	Met or exceeded expected results	Pass	Radios on are CS so Loss link does not affect. Loss of downlink would prevent transponder verification directly but could get confirmation from ATC.	Pass
31-3	At a minimum, relay the following information to ATC: - Last known altitude - Heading - Destination	Pilot performs two-way radio communications to inform ATC of: - Last known altitude - Heading - Destination	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass

	- Location when the link was lost (Latitude/Longitude), and - Expected lost-link behavior	- Location when the link was lost (Latitude/Longitude), and - Expected lost-link behavior									
32-1	Refer to published troubleshooting procedures when troubleshooting a lost command link.	Pilot references the POH to troubleshoot lost-link conditions from the CS while in flight.	Pass	Met or exceeded expected results	Pass	Follows a published checklist to troubleshoot	Pass	Met or exceeded expected results	Pass		Pass
32-2	Continue or terminate the flight based upon the outcome of link troubleshooting procedures.	The pilot determines either to continue or terminate flight, based on lost-link troubleshooting results.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
32-3	Communicate the outcome of troubleshooting to ATC.	Pilot performs two-way radio communication with ATC about the lost-link troubleshooting outcome.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass

Flight Card Description	Flight Test #6	**Test Case Description**	Perform Lost-Link, In-Flight Emergency, and Emergency Landing Procedures		
Validation Attempt ID	All	**Data Collector ID**	Collective	**UAS Operator ID**	All
Researcher/Assessor's ID	All	**Date Tested**	June 6, 2017	**Test Case (Pass/Fail)**	N/A

Assumption	**Assumptions:**
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	**Operational Procedures Validated**
33	Operations During Command and Control Degradation and Loss - General
34	Operations During Periods of Decreased Sensory Cues from Aircraft and Environment
35	In-Flight Emergencies - Propulsion Failure
44	Emergency Landing - Ditching Site Selection
45	Emergency Landing - Flight Termination

OP #	**Operational Procedure/ Process Step**	**Expected Results**	Final Result **Pass / Fail / Not Observed/ Not Applicable / Suspended**	Observer 1 **Actual Results**	Observer 1 **Pass / Fail / Not Observed/ Not Applicable / Suspended**	Observer 2 **Actual Results**	Observer 2 **Pass / Fail / Not Observed/ Not Applicable / Suspended**	Observer 3 **Actual Results**	Observer 3 **Pass / Fail / Not Observed/ Not Applicable / Suspended**	Observer 4 **Actual Results**	Observer 4 **Pass / Fail / Not Observed/ Not Applicable / Suspended**
33-1	While operating a UAS, monitor the command and control link integrity. Should	The pilot detects a degraded command link and reacts by referring to	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected	Pass		Pass

	degraded link performance be encountered, execute appropriate procedures to address the situation.	published procedures for degraded link performance.						results			
33-2	During command and control degradation or loss of signal, execute appropriate checklists, troubleshooting, communication protocols, and contingencies for re-establishing the command link.	The pilot utilizes the appropriate checklists and procedures to troubleshoot/attempt to restore the command link.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
34-1	Determine if full or partial loss of sensory cues exist.	The pilot acknowledges and inventories degraded performance of required displays and flight information.	Pass	Met or exceeded expected results	Pass		Not Observed	Met or exceeded expected results	Pass		N/E
34-2	If applicable, use UAS sensors to regain or maintain orientation and spatial awareness of the UAS.	The pilot uses available sensors to maintain controlled flight.	Pass	Met or exceeded expected results	Pass		Not Observed	Met or exceeded expected results	Pass		N/E
34-3	Manage multiple telemetry datalinks independently, if applicable.	The pilot chooses the data link with the strongest signal while demonstrating awareness of the status of other links.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Auto and displayed information	Pass
34-4	Maintain situation awareness of the UAS by scanning displays and instrumentation.	The pilot continues their scan of available instrumentation and maintains controlled, stable flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
34-5	Monitor UA caution/alert status.	The pilot acknowledges any caution or alert notifications as they occur.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
34-6	If multiple emergences exist, manage them using aeronautical decision making techniques.	The pilot prioritizes the most significant emergency above less significant anomalies.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
34-7	If required, calculate position, heading, and airspeed to determine proper heading and time to designated location.	The pilot determines their position, heading, and airspeed using alternative means.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
34-8	If equipped, be familiar with ground data terminal	The pilot uses the GDT antenna to aid in	Pass	Met or exceeded expected results	Pass	Can orient to aircraft based	Pass	Met or exceeded	Pass		Pass

	azimuth and dead reckoning to maintain UA position.	determining their position.				upon link signal strength		expected results			
35-1	Identify and address engine failure notifications with the appropriate emergency procedures, as applicable.	The pilot refers to the appropriate published procedures to address an engine failure and takes appropriate action.	Pass	Met or exceeded expected results	Pass	Scenario: Stuck throttle servo	Pass	Met or exceeded expected results	Pass	Stuck Throttle	Pass
35-2	Maintain aircraft control and configure the aircraft to achieve optimum glide, as required.	The pilot ensures optimum glide is flown.	Pass	Met or exceeded expected results	Pass	Pilot takes note of rate of descent and airspeed	Pass	Met or exceeded expected results	Pass	auto Airspeed	Pass
35-3	While performing an emergency landing, select landing areas that pose minimal risk to personnel and property on the ground.	The pilot identifies a lowest-risk landing area.	Pass	Met or exceeded expected results	Pass	Usually coordinates with payload operator to identify a safe area	Pass	Met or exceeded expected results	Pass		Pass
35-4	During an emergency landing, take high-volume transects and approaches into consideration and maneuver to avoid them whenever possible.	The pilot attempts to avoid busy airspace and airways.	Pass	Met or exceeded expected results	Pass	Not a normal consideration for military operations. This could be coordinated if required.	Pass	Met or exceeded expected results	Pass		Pass
35-5	If a suitable landing site is unavailable, determine the best area to terminate the flight to minimize risk to personnel and property on the ground.	The pilot chooses a flight termination point in a location that minimizes risk.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
35-6	Determine effects of weather on landing/ditching location.	The pilot demonstrates factoring weather into consideration when picking a landing/ditching location.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
35-7	Address all applicable emergency procedures as practical.	The pilot addresses additional emergencies and prioritizes them by criticality.	Pass	Met or exceeded expected results	Pass	In the case of the stuck throttle, the throttle was stuck at a low throttle setting. The pilot prioritized the effect of the low throttle setting over that of the	Pass	Met or exceeded expected results	Pass		Pass

						frozen servo.					
35-8	Set transponder to 7700 if/when able to do so.	The pilot sets the transponder accordingly.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
35-9	Communicate an engine failure to ATC as soon as practical.	The pilot communicates the engine failure to ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
35-10	Notify ground crew, if required.	The pilot notifies crew as applicable.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass		Pass
44-1	Execute ditching maneuvers in accordance with published procedures for the given system.	The pilot sets up to ditch the aircraft in accordance with established procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
44-2	Select ditching locations based upon the ability to minimize risk to personnel and property on the ground.	A remote or unpopulated location is chosen for ditching.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
44-3	When practical, communicate ditching locations and pilot intentions to ATC.	The pilot communicates their intent and ditching location to ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
45-1	Perform flight termination, if required.	Flight termination is initiated if the pilot deems ditching is impractical.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
45-2	Execute flight termination according to established flight termination procedures for the given system.	Flight termination is executed according to published procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
45-3	When executing flight termination, monitor the execution of the maneuver.	The pilot monitors the termination procedure and verifies that it completes correctly.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
45-4	Select flight termination locations bases upon the ability to minimize risk to personnel and property on the ground.	The pilot chooses a remote location for flight termination.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
45-5	Notify ATC of intent to terminate and provide the flight termination position.	The pilot relays their intent to terminate the flight and the termination location to ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results	Pass	Ditch and Terminate are the same for this platform.	Pass
45-6	Upon execution of flight	The pilot engages a fuel	Pass	Met or exceeded	Pass	Engine	Pass	Met or	Pass	Ditch and	Pass

	termination, engage the fuel cutoff, if applicable.	cutoff during termination, if applicable.		expected results		ignition is cut upon termination; parachute is deployed.		exceeded expected results		Terminate are the same for this platform.	

Flight Card Description	Flight Test #7	Test Case Description	Perform En-route Operations, In-Flight Emergencies, and Emergency Landing Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All

Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	Operational Procedures Validated
14a	En-route Operations - General
14b	En-route Operations - Navigation
36	In-Flight Emergencies - Two-way Communications Failure
37	In-Flight Emergencies - Navigation Failure - GPS or Other System
39	In-Flight Emergencies - Uncontrolled Flight
45	Emergency Landing - Flight Termination

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
14a-1	Use proper communication procedures when using radar services (as applicable).	The pilot uses two-way communication with ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-1-1	Contact Memphis Center on 120.8MHz.	The pilot changes the two-way radio frequency to 120.8 while in flight and contact the Memphis ARTCC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-2	Obtain ATC clearance.	Pilot performs two-way radio communication to obtain an ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

14a-2-1	Request clearance for transitioning into R-2104B	Pilot performs two-way radio communication to request clearance into R-2104B restricted airspace.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-3	Respond to ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-3-1	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot reads back the ATC clearance approval using standard aviation terminology.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-4	Comply with ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-4-1	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot turns the UA into R2104B, remain within that airspace, climb to 5,000 feet MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-5	Use standard aviation phraseology when communicating with ATC.	Pilot uses standard aviation phraseology when communicating with ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-6	Set communication frequencies, navigation systems, and transponder codes to ensure compliance with ATC clearances.	Pilot switches radio navigation frequencies and transponder code from within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-7	Conduct any required communication frequency changes.	Pilot switches two-way radio frequencies from within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-8	Use available systems (if equipped) to detect icing conditions.	Pilot uses the CS to detect icing.	Pass	Met or exceeded expected results	Pass	No payload operator; can use payload to detect airframe icing	Not Observed	Met or exceeded expected results.	Pass		Pass
14a-8-1	Determine if the pitot tube has ice.	Pilot uses the CS to detect icing on the pitot tube.	Pass	Met or exceeded expected results	Pass		Not Observed	Met or exceeded expected results.	Pass		Pass

14a-8-2	Determine if the UA has structural ice.	Pilot uses the payload video to inspect the UA for structural icing.	Pass	Met or exceeded expected results	Pass		Not Observed	Met or exceeded expected results.	Pass		Pass
14a-9	Monitor aircraft electrical, propulsion, and datalink performance.	Pilot monitors status and health of electrical, propulsion, and datalink systems.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-9-1	Determine if current bus voltage is within limitations.	Pilot monitors bus voltage and determine it is within the POH-required limits.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Auto and # display	Pass
14b-1	Monitor aircraft's position throughout the flight and maintain course in accordance with ATC instructions/clearance.	Pilot determines the location of the UA on a location display.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-1-1	Determine current location	Pilot determines current location on the location display and/ or GPS coordinate display.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-1-1	Turn and maintain 130 degrees.	Pilot turns from 360 degrees to 130 degrees.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-2	Intercept and track a given course, radial (if equipped), or bearing, as appropriate.	Pilot plots a course and command the UA heading.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	GPS Pt to PT only. Pilot could calculate equivalent radial intercept with VOR position information.	N/A
14b-2-1	Determine the course heading to Nashville, TN.	Pilot plots a course heading from the UA's current position direct to Atlanta, GA. While factoring winds.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

14b-2-2	Determine a ground track to Nashville, TN.	Pilot determines a ground track necessary for a direct course to Atlanta, GA.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-3	Determine loss of GPS or navigation solution if it occurs.	The pilot interprets the GPS health and status within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	WCA with secondary menus display for more detail information	Pass
14b-4	Maintain the appropriate altitude and headings.	Pilot turns the UA and change altitude while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-4-1	Turn to heading 350 degrees.	Pilot turns the UA to 350 degrees magnetic.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-4-2	Climb and maintain 10,000 feet MSL.	Pilot climbs the UA to 10,000 MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Used 5,000 ft	Pass
14b-4-3	Perform dead reckoning navigation if required.	Pilot uses payload video to navigate back to a landing airport.	Pass	Met or exceeded expected results	Pass	No payload operator present	Not Observed	Met or exceeded expected results.	Pass		Pass
14b-4-4	Return to Huntsville International Airport via heading and airspeed.	Pilot uses the UA's heading and ground speed to return to HSV.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-4-6	Use payload video to enter the traffic pattern at Huntsville International Airport.	Pilot uses payload video to navigate into the traffic pattern.	Pass	Met or exceeded expected results	Pass	No payload operator present	Not Observed	Met or exceeded expected results.	Pass		Pass
14b-6	Maintain course by reference to established waypoints/steer points or other navigational references, as applicable.	Pilot remains on an established course and changes course once waypoints are achieved.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

14b-7	If equipped, be able to identify surface features to chart symbols.	Pilot performs map to video correlation between the payload video and location display to identify natural and man-made terrain features.	Pass	Met or exceeded expected results	Pass	No payload operator present	Not Observed	Met or exceeded expected results.	Pass		N/E
14b-8	Navigate by means of precomputed headings, groundspeeds, and elapsed time (if required).	Pilot determines a required heading +/- 10 degrees, groundspeed +/- 10 knots, and time +/- 3 minutes.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Manual calculation from provided data	Pass
14b-9	Correct for wind to maintain desired route and performance.	The Pilot acknowledges and corrects for wind to maintain desired course.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10	Remain within planned route described in the flight plan.	The Pilot commands the UA to maintain the desired course, speed, and altitude outlined in the flight plan.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-1	Obtain ATC clearance.	Pilot performs two-way radio communication to obtain an ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-2	Request clearance for transitioning into R-2104B	Pilot performs two-way radio communication to request clearance into R-2104B restricted airspace.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-3	Respond to ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-4	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot reads back the ATC clearance approval using standard aviation terminology.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-5	Comply with ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-6	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot turns the UA into R2104B, remain within that airspace, climb to 5,000 feet MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Used simulated airspace	Pass

36-1	Set transponder to 7600.	The pilot sets the transponder code to 7600 during a communication failure.	Pass	Met or exceeded expected results	Pass	Sets transponder code	Pass	Met or exceeded expected results.	Pass		Pass
36-2	When available, utilize alternative means of communication to communicate with ATC.	Alternative means to communicate with ATC are identified during a two-way communication failure.	Pass	Met or exceeded expected results	Pass	Pilot can use phone	Pass	Met or exceeded expected results.	Pass	Phone, Personnel	Pass
36-3	Prioritize routing as required for IFR communications failures.	The pilot correctly prioritizes routes using AVEF.	Pass	Met or exceeded expected results	Pass	Not equipped to fly instrument routes; No RNAV	Fail	Met or exceeded expected results.	Pass		Pass
36-4	Prioritize altitudes as required for IFR communications failures.	The pilot correctly prioritizes altitudes for IFR communication failures.	Pass	Met or exceeded expected results	Pass	Possible; Not observed	Not Observed	Met or exceeded expected results.	Pass		Pass
37-1	Address navigation system failures as soon as practical.	Navigation failures are addressed as they are identified by the pilot.	Pass	Met or exceeded expected results	Pass	Possible; Not observed	Not Observed	Met or exceeded expected results.	Pass	WCA	Pass
37-2	Address a navigation failure in accordance with established procedures for the given system.	The pilot addresses navigation system failures in accordance with published procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
37-3	Perform dead reckoning navigation if required.	The pilot uses dead reckoning to perform navigation.	Pass	Met or exceeded expected results	Pass	Use payload to assist if required; Notional in this case	Pass	Met or exceeded expected results.	Pass	Using Payload if available. If not, last position.	Pass
37-4	Notify ATC of intentions.	The pilot notifies ATC of their intentions when addressing a navigation failure.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
37-5	Refer to off-site landing (ditching) or termination procedures, as required, if flight cannot be continued with a failed navigation system.	The pilot chooses to ditch or terminate if navigation systems cannot be restored.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		N/A

39-1	Address equipment failures that can lead to or hinder the recovery from uncontrolled flight.	The pilot troubleshoots equipment failures related to flight control systems.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
39-2	Address equipment failures in accordance with established procedures.	The pilot addresses equipment failures per published procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
39-3	Interpret and react to system cues that warn of the possibility of entering into a state of uncontrolled flight.	The pilot acknowledges and reacts to warnings/alerts that are indicators of uncontrolled flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
39-4	Avoid configurations and flight regimes in which the UAS is susceptible to a loss of control.	The pilot acknowledges and avoids flight configurations where the aircraft is inherently unstable.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
39-5	Recognize and recover from unusual attitudes, when UAS capabilities allow such control.	The pilot recovers from unusual attitudes.	Pass	Not performed	Not observed.		Pass	Software inhibits the capability of intentionally entering a stall or spin.	Not Observed	Auto system	Pass
39-6	Execute appropriate stall/spin recovery strategies for multiple types of stalls/spins, when UA capabilities allow such control.	The pilot recovers from a stall/spin.	Pass	Met or exceeded expected results	Pass	Robust envelope protection system prevents the pilot from stalling and getting into a stall/spin scenario.	N/A	Met or exceeded expected results.	Pass	No Stall due to auto protect so no spin either	N/A
39-7	Notify ATC of a loss of control as soon as practical.	The pilot notifies ATC of a loss of aircraft control.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
39-8	Know and execute any published procedures to address any loss of UAS control.	The pilot addresses loss of control with published procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
45-1	Perform flight termination, if required.	The pilot terminates the flight if controlled flight cannot be regained.	Pass	Met or exceeded expected results	Pass	Pilot terminates in the event of a loss of control; deploys a parachute.	Pass	Met or exceeded expected results.	Pass		Pass

45-2	Execute flight termination according to established flight termination procedures for the given system.	Flight termination is in accordance with established procedures for the system.	Pass	Met or exceeded expected results	Pass	Followed established procedures	Pass	Met or exceeded expected results.	Pass		Pass
45-3	When executing flight termination, monitor the execution of the maneuver.	The pilot monitors flight termination and confirms termination with ATC.	Pass	Met or exceeded expected results	Pass	Follows telemetry; reports last known position prior to loss of link at touchdown after initiating flight termination.	Pass	Met or exceeded expected results.	Pass		Pass
45-4	Select flight termination locations bases upon the ability to minimize risk to personnel and property on the ground.	The pilot chooses a remote location for flight termination.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
45-5	Notify ATC of intent to terminate and provide the flight termination position.	The pilot notifies ATC of the intent to terminate and provides the location of the termination point.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
45-6	Upon execution of flight termination, engage the fuel cutoff, if applicable.	The fuel cutoff is engaged when the flight is terminated.	Pass	Met or exceeded expected results	Pass	Engine is killed upon initiating flight termination.	Pass	Met or exceeded expected results.	Pass		Pass

Flight Card Description	Flight Test #8	**Test Case Description**	Perform Cruise Power Settings, In-Flight Emergencies, and Emergency Landing Procedures		
Validation Attempt ID	All	**Data Collector ID**	Collective	**UAS Operator ID**	All
Researcher/Assessor's ID	All	**Date Tested**	June 6, 2017	**Test Case (Pass/Fail)**	N/A

Assumption #	**Assumptions:**
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	**Operational Procedures Validated**
18	Cruise Power Settings
40	In-Flight Emergencies - Emergency Descent
41	Emergency Landing - Communication
42	Emergency Landing - Approach
43	Emergency Landing - Touchdown

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
18-1	Monitor UA fuel/battery status while in flight.	The pilot determines the status of fuel/ battery during flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-1-1	Determine fuel burn rate.	The pilot determines the rate of fuel consumption from within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-1-1	Determine fuel consumed.	The pilot determines the amount of fuel consumed from within the CS since engine start.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-1-2	Determine fuel remaining.	The pilot determines the amount of fuel remaining from within the CS since engine start.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-2	Adjust power settings as required to maintain desired performance.	The pilot adjusts power settings for maximum range or endurance.	Pass	Met or exceeded expected results	Pass	Indirectly set through airspeed settings.	Pass	Met or exceeded expected results.	Pass		Pass
18-3	Perform fuel burn/battery life calculations such that the destination is reached with the required fuel/battery reserve remaining.	The pilot calculates fuel/ battery remaining requirements to complete a mission with reserve capacity from the CS while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-3-1	Determine the fuel required with a 30-minute reserve to fly to Memphis International Airport.	Pilot is able to correctly calculate the fuel requirements, taking into account GS, time,	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Multiple Map and fuel measurements for pilot to	Pass

		distance, fuel burn rate, and reserve from within the CS while in flight.								calculate from	
18-4	Re-evaluate performance data as required to reach the destination at the required time with the required fuel/battery reserves.	The pilot re-evaluates performance/endurance, including fuel/ battery reserves after a change in the mission plan.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-4	Climb to 10,000 feet	The pilot re-calculates the fuel requirements, taking into account ground speed, time, distance, fuel burn rate, and reserve from within the CS while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Used 5,000 ft	Pass
18-5	Determine any new performance capabilities or limitations that may result from alterations in the flight plan or an in-flight emergency.	The pilot determines if any performance limitations have changed as a result of altering the flight plan form the CS while in flight.	Pass	Met or exceeded expected results	Pass	Generator Failure chosen here: Shut of non-essential systems creates new limitations.	Pass	Met or exceeded expected results.	Pass	Gen Failure; Batt only, reduced loads	Pass
40-1	Execute proper division of attention in an emergency descent scenario.	The pilot prioritizes emergencies.	Pass	Met or exceeded expected results	Pass	See previous example for prioritization of emergencies.	Pass	Met or exceeded expected results.	Pass		Pass
40-2	When performing an emergency decent, ensure that any performance limitations are not exceeded.	The aircraft does not exceed V_{NE} during the descent.	Pass	Met or exceeded expected results	Pass	Envelope protection limits airspeeds.	Pass	Met or exceeded expected results.	Pass	auto	Pass
40-3	Perform emergency descents as applicable to the aircraft's configuration (flaps, landing gear, and engine power setting) as applicable.	The pilot configures the aircraft for emergency descent per established procedures.	Pass	Met or exceeded expected results	Pass	Shut off non-essential systems for GEN fail.	Pass	Met or exceeded expected results.	Pass	same as normal	Pass
40-4	Notify ATC as soon as practical when executing an emergency decent.	The pilot notifies ATC of emergency descent when practical.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
40-5	Execute all descent procedures as time allows while maintaining aircraft control.	The pilot maintains positive control during the emergency descent maneuver.	Pass	Met or exceeded expected results	Pass	Cane be done; not performed in this instance	Not Observed	Met or exceeded expected results.	Pass		Pass
40-6	If applicable, brief and perform hand-off procedures to the landing	A control station handoff is performed to meet the needs of the emergency.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

	pilot.										
40-7	Determine if landing or flight termination is suitable.	The pilot makes a decision to land or terminate the flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
41-1	Communicate emergency landing flight plans/or routes with ATC as soon as practical.	The pilot communicates their emergency route to ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Gen Failure	Pass
41-2	Notify ATC as soon as practical when deviating from a clearance.	The pilot notifies ATC of a deviation from a known clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
41-3	Maintain a sterile cockpit during emergency maneuvers.	The pilot maintains a sterile cockpit.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
41-4	When the situation warrants, provide ATC with information regarding the nature of the emergency and intentions.	The pilot communicates their intention and the nature of their emergency to ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
41-5	During the transition portions and prior to landing, maintain communication with ATC and any required ground crew.	The pilot maintains open communications with ATC and other required personnel.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
42-1	Perform emergency approaches in accordance with procedures for the given system.	Emergency approaches are conducted in accordance with established procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
42-2	Monitor airspeed, altitude, and other flight performance parameters while on approach.	The pilot identifies deviations in airspeed, altitude, and other performance parameters and corrects for them while on approach.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Auto and pilot	Pass
42-3	Choose an emergency landing location that minimizes risk to persons or property on the ground.	The pilot chooses a remote location for the emergency landing.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
42-4	Determine effects of weather on emergency landing conditions.	The pilot lands into the wind.	Pass	Met or exceeded expected results	Pass	Pilot coordinates to get weather when possible (emergency landing conducted at takeoff site).	Pass	Met or exceeded expected results.	Pass		Pass
42-5	Ensure obstacle clearance to	The pilot avoids obstacles	Pass	Met or exceeded expected	Pass		Pass	Met or exceeded	Pass	Map and if	Pass

	the best extent possible when executing an emergency landing.	throughout the procedure.		results				expected results.		available video	
42-6	Adhere to any published emergency approach and landing procedures that may exist for the system.	The pilot follows established emergency landing procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Agreed to UAS approach	Pass
43-1	Complete any additional procedures that may be required after touching down.	The pilot completes any other documented procedures that are required to follow an emergency landing.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Gen Failure TALS abort override (pilot kills engine if UAS does not do it properly)	Pass
43-2	Maintain communications with ATC.	The pilot maintains communication with ATC throughout the emergency.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
43-3	Upon touchdown, communicate with a visual observer (if required) or other necessary ground support personnel to ensure that the approach path remains clear.	The pilot coordinates with crew to ensure that the approach path is clear.	Pass	Met or exceeded expected results	Pass	Normal operations in sterile airspace, Coordination with a VO to clear airspace is possible.	Not Observed	Met or exceeded expected results.	Pass	Crew Chief	Pass
43-4	Determine missed approach requirements.	The pilot executes a missed approach if missed approach criteria are met.	Pass	Met or exceeded expected results	Pass	Missed approaches are an absolute last resort in a GEN fail scenario. However, it is possible to perform a "wave off" if required.	Pass	Met or exceeded expected results.	Pass		Pass
43-5	Complete emergency landings in accordance with any published emergency procedures for the given system.	Emergency landings are executed in accordance with published procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

Flight Card Description	Flight Test #9	Test Case Description	Perform En-Route Operations, Descent from Cruise, Approach, Landing, and Ground Support Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All

Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
6	AIM if available in CS
8	UA is airborne
8	A simulated ATC entity is available

OP #	Operational Procedures Validated
17	En-route Operations - Descents
20	Descent From Cruise - General
21	Approach - General
22	Landing - Communications
23	Approach and Landing (Human in the Loop)
24	Go Around
25	Ground Support

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
17-1	Conduct descents in accordance with ATC clearance.	The pilot complies with ATC clearance to descend.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
17-2	Conduct descents with regard to UAS limitations.	UAS airspeed and structural limitations are not exceeded.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
17-3	Do not exceed UAS performance limitations in descents.	UAS airspeed and structural limitations are not exceeded.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

20-1	Descend to pattern altitude or an approach fix/initial approach waypoint in a manner that does not impede or decrease the safety of other air traffic.	The pilot maintains separation from other traffic while descending to pattern altitude.	Pass	Met or exceeded expected results	Pass	Aircraft not equipped to maintain separation without a VO	Fail	Met or exceeded expected results.	Pass	With ATC separation or VO. No internal DAA system.	Pass
20-2	If unable to perform a published instrument approach, coordinate approach procedures with ATC prior to arrival at the initial approach fix.	The pilot coordinates their approach with ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
20-3	Comply with ATC clearance to descend, if applicable.	The pilot complies with ATC clearance to descend.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
20-4	Ensure that the UA is configured for descent.	The UA is configured for descent (flaps, landing gear, etc.).	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
21-1	Monitor the airspeed, altitude, heading, and system health parameters while on approach.	The pilot monitors airspeed, altitude, heading, and system health while on approach and executes a missed approach if the UA falls within missed approach parameters.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
21-2	Perform approaches per the published approach plates unless a standardized approach exists for specific unmanned system being flown.	The pilot performs the approach per established procedures, whatever they may be.	Pass	Met or exceeded expected results	Pass	Limited ability to perform manned aircraft approaches, but may use standardized approaches that are unique to the platform.	Pass	Met or exceeded expected results.	Pass		Pass
21-3	Ensure that the final approach path is clear of aircraft and obstacles.	The final approach path is clear throughout approach and the pilot reacts correctly to a traffic conflict.	Pass	Met or exceeded expected results	Pass	PIC cannot clear traffic without a VO (notional)	Pass	Met or exceeded expected results.	Pass	Pilot would coordinate (No DAA system)	Pass

21-4	If a visual observer (VO) is the sole means of clearing the airspace for an approach, ensure that two-way communication with the observer is maintained throughout the approach.	If a VO is used to clear the airspace, the pilot maintains communication with them throughout the approach.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Radio or phone	Pass
22-1	Establish communication with local ATC when arriving at the destination or entering controlled airspace, as applicable.	The pilot makes initial contact with ATC prior to entering controlled airspace.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
22-2	Maintain communication with ATC when operating in controlled airspace. Acknowledge and read back clearances per AIM 4-4-7.	The pilot maintains communication with ATC and properly acknowledges clearances, reading them back when required.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
22-3	Use standard phraseology to obtain ATC clearance for landing.	Then pilot uses standard ATC phraseology when requesting clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
23-1	Choose landing procedure appropriate to the type of approach and prevailing weather conditions.	The pilot chooses an approach that is appropriate to the prevailing weather conditions at the destination airport.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Requires ground personnel to change runways	Pass
23-2	Contact ATC and request clearance to land; acknowledge landing clearance when received.	The pilot requests and acknowledges landing clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
23-3	Ensure that the UA is configured for landing prior to touchdown.	The UA is configured for landing as described in published procedure/POH.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Auto flaps only. Invisible to RPIC	Pass
24-1	Communicate the go-around to ATC as soon as practical.	The pilot communicates the go-around(s) to ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

24-2	Abort landing prior to commitment point.	The pilot makes the decision to abort prior to a predetermined commitment point.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
24-3	Maintain positive rate of climb.	The pilot maintains positive climb to a predetermined altitude during the abort procedure.	Pass	Met or exceeded expected results	Pass	Verify positive climb	Pass	Met or exceeded expected results.	Pass	Auto until Knobs mode selected	Pass
24-4	Maintain runway centerline.	The pilot maintains runway centerline during the initial climb.	Pass	Met or exceeded expected results	Pass	Climb to specified point	Pass	Met or exceeded expected results.	Pass	Preprogrammed	Pass
24-5	Climb to a predetermined altitude that ensures obstacle clearance.	The pilot climbs the UA to an altitude that assures obstacle clearance.	Pass	Met or exceeded expected results	Pass	Climb to specified point	Pass	Met or exceeded expected results.	Pass		Pass
24-6	Follow applicable missed approach procedures.	Published missed approach procedures are followed (as applicable).	Pass	Met or exceeded expected results	Pass	As applicable	Pass	Met or exceeded expected results.	Pass	Pre-coordinated but possible UAS specific version.	Pass
24-7	Coordinate with ATC as required to re-attempt the approach.	The pilot coordinates with ATC to re-attempt an approach.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
25-1	If required for landing, coordinate with any ground support personnel and brief them on landing procedures.	The pilot coordinates with ground personnel if required.	Pass	Met or exceeded expected results	Pass	Part of standard procedure (notional)	Pass	Met or exceeded expected results.	Pass		Pass

Flight Card Description	Flight Test #10	Test Case Description	Perform Normal Operational Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All
Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
6	AIM if available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	Operational Procedures Validated
20	Descent From Cruise - General
21	Approach - General
24	Go Around
25	Ground Support
26	Approach and Landing (Automated)

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
20-1	Descend to pattern altitude or an approach fix/initial approach waypoint in a manner that does not impede or decrease the safety of other air traffic.	The pilot descends to pattern altitude or an approach fix/initial approach waypoint in a manner that does not impede or decrease the safety of other air traffic.	Pass	Met or exceeded expected results	Pass	Use payload of VO. Payload is not ideal, but is capable of detecting aircraft with IR.	Not Observed	Met or exceeded expected results.	Pass	Payload (if available)/ VO	Pass
20-2	If unable to perform a published instrument approach, coordinate approach procedures with ATC prior to arrival at the initial approach fix.	(Pilot is unable to perform a published instrument approach) Pilot coordinates a new approach procedure with ATC prior to arrival at the initial approach fix.	Pass	Not capable	Fail	Pilot performs a platform specific approach	Pass	Met or exceeded expected results.	Pass	UAS published approaches are typical operations	Pass
20-3	Comply with ATC clearance to descend, if applicable.	The pilot complies with an ATC clearance to descent, if applicable.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
20-4	Ensure that the UA is configured for descent.	The pilot properly configures the UA for descent.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
21-1	Monitor the airspeed, altitude, heading, and system health parameters while on approach.	The pilot monitors the airspeed, altitude, heading, and system health parameters while on approach.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Both Pilot and auto	Pass
21-2	Perform approaches per the	The pilot executes the	Pass	Not capable	Fail	Pilot performs a	Pass	Met or	Pass		Pass

	published approach plates unless a standardized approach exists for specific unmanned system being flown.	instrument per the published approach plates unless a standardized approach exits for specific unmanned system being flown.				platform specific approach		exceeded expected results.			
21-3	Ensure that the final approach path is clear of aircraft and obstacles.	The pilot determines that the final approach path is clear of aircraft and obstacles.	Pass	Met or exceeded expected results	Pass	If VO is used	Pass	Met or exceeded expected results.	Pass	Payload (If available)/ VO	Pass
21-4	If a visual observer (VO) is the sole means of clearing the airspace for an approach, ensure that two-way communication with the observer is maintained throughout the approach.	If a visual observer (VO) is the sole means of clearing the airspace for an approach, the pilot ensures two-way communication with the observer throughout the approach.	Pass	Met or exceeded expected results	Pass	Communication was notional in this case	Pass	Met or exceeded expected results.	Pass	Military typically uses airspace and procedure. When they have used CoA VO is used.	Pass
24-1	Communicate the go-around to ATC as soon as practical.	The pilot notifies ATC as soon as practical when a go-around is executed.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
24-2	Abort landing prior to commitment point.	The pilot aborts the landing prior to commitment point.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Pilot and auto	Pass
24-3	Maintain positive rate of climb.	The pilot maintains a positive rate of climb.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Auto	Pass
24-4	Maintain runway centerline.	The pilot maintains runway centerline.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Auto and RPIC. Preconfigured by RPIC for route and altitude	Pass
24-5	Climb to a predetermined altitude that ensures obstacle clearance.	The pilot climbs to a predetermined altitude that ensures obstacle clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
24-6	Follow applicable missed approach procedures.	The pilot follows applicable missed approach procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
24-7	Coordinate with ATC as required to re-attempt the approach.	The pilot obtains ATC clearance to re-attempt the approach.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

25-1	If required for landing, coordinate with any ground support personnel and brief them on landing procedures.	If required for landing, the pilot coordinates with any ground support personnel and briefs them on landing procedures.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
26-1	Monitor the aircraft on approach and ensure that it conforms to known performance limitations on approach and landing.	The pilot monitors the aircraft on approach and ensures that it conforms to all performance limitations during approach and landing.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
26-2	If required and the UAS is so equipped, make manual control inputs to assist in guiding the UAS while on approach.	If required and the UAS is so equipped, the pilot manually controls the UAS during approach.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		N/A
26-3	If applicable, assume manual control of the UAS in the event of an emergency.	If applicable, the pilot assumes manual control of the UAS during emergency situations.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Auto	N/A

Flight Card Description	Flight Test #11	Test Case Description	Perform Post Landing Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All
Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	Operational Procedures Validated
27	Post-Landing - Communications
28	Post-Landing - Taxi
29	Post-Landing - Ground Support

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
27-1	Maintain communication with the applicable ATC element upon landing.	The pilot establishes and maintains 2-way communication with the applicable ATC element upon landing.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
27-2	Follow ATC instructions for taxi.	The pilot establishes and maintains 2-way communication with the applicable ATC element during taxi operations.	Pass	Met or exceeded expected results	Pass	Aircraft does not taxi	N/A	Met or exceeded expected results.	Pass	No Taxi	N/A
28-1	Taxi on cleared route.	The pilot uses the CS and camera if available to taxi on the cleared route.	Pass	Met or exceeded expected results	Pass	Aircraft does not taxi	N/A	Met or exceeded expected results.	Pass	No Taxi	N/A
28-2	Maintain a taxi speed at the marshaller's pace (if required), or as appropriate to maintain separation from other traffic.	The pilot follows the marshaller's commands or as appropriate to maintain separation from other traffic.	Pass	Met or exceeded expected results	Pass	Aircraft does not taxi	N/A	Met or exceeded expected results.	Pass	No Taxi	N/A
28-3	Remain a safe distance from other aircraft.	The pilot maintains a safe taxi speed in order to enable a full-stop to avoid other aircraft or obstacles.	Pass	Met or exceeded expected results	Pass	Aircraft does not taxi	N/A	Met or exceeded expected results.	Pass	No Taxi	N/A
28-4	Avoid hazards on taxiway surface.	The pilot uses the CS and camera, if available, to avoid hazards on the taxiway surface.	Pass	Met or exceeded expected results	Pass	Aircraft does not taxi	N/A	Met or exceeded expected results.	Pass	No Taxi	N/A
28-5	Taxi according to applicable signage and warning lights.	The pilot uses the CS, camera, or VO (if available) to avoid	Pass	Met or exceeded expected results	Pass	Aircraft does not taxi	N/A	Met or exceeded expected	Pass	No Taxi	N/A

		hazards on the taxiway surface.						results.			
29-1	Verify UA is parked in designated location.	The pilot uses the CS, camera, marshaller, or VO (if available) to verify that the UA is parked in it designated location.	Pass	Met or exceeded expected results	Pass	Aircraft does not taxi	N/A	Met or exceeded expected results.	Pass	No Taxi	N/A
29-2	Shut down the engine.	The pilot successfully shuts down the engine.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Coordinated with Crew Chief	Pass
29-3	If required, confirm engine shutdown with ground crew.	The pilot confirms the successful engine shutdown with the ground crew, if required.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Coordinated with Crew Chief	Pass
29-4	Perform a post-flight inspection of GCS and associated systems.	The pilot follows the appropriate checklist(s) to perform the post-flight inspection of CS and associated systems.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
29-5	Coordinate with ground crews (if required) to perform a post-flight inspection of the UA.	The pilot communicates with the appropriate ground crews (if required) to perform a post-flight inspection of the UA.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

Flight Card Description	Flight Test #12	Test Case Description	Perform En-Route, Cruise Power Settings, Weather Monitoring, and Control Station Handoff Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All
Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	Operational Procedures Validated
14a	En-route Operations - General
14b	En-route Operations - Navigation
18	Cruise Power Settings
19	Weather Monitoring
30	Control Station Handoff - General

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	Operational Procedure/ Process Step	Expected Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended	Actual Results	Pass / Fail / Not Observed/ Not Applicable / Suspended
14a-1	Use proper communication procedures when using radar services (as applicable).	The pilot uses two-way communication with ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-1-1	Contact Memphis Center on 120.8MHz.	The pilot changes the two-way radio frequency to 120.8 while in flight and contact the Memphis ARTCC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-2	Obtain ATC clearance.	Pilot performs two-way radio communication to obtain an ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-2-1	Request clearance for transitioning into R-2104B	Pilot performs two-way radio communication to request clearance into R-2104B restricted airspace.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-3	Respond to ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-3-1	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot reads back the ATC clearance approval using standard aviation terminology.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

14a-4	Comply with ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-4-1	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot turns the UA into R2104B, remain within that airspace, climb to 5,000 feet MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-5	Use standard aviation phraseology when communicating with ATC.	Pilot uses standard aviation phraseology when communicating with ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-6	Set communication frequencies, navigation systems, and transponder codes to ensure compliance with ATC clearances.	Pilot switches radio navigation frequencies and transponder code from within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-7	Conduct any required communication frequency changes.	Pilot switches two-way radio frequencies from within the CS.	Pass	Met or exceeded expected results	Pass	No payload operator	Pass	Met or exceeded expected results.	Pass		Pass
14a-8	Use available systems (if equipped) to detect icing conditions.	Pilot uses the CS to detect icing.	Pass	Met or exceeded expected results	Pass	Pilot would notice airspeed problems if pitot tube blocked by ice	Not Observed	Met or exceeded expected results.	Pass		Pass
14a-8-1	Determine if the pitot tube has ice.	Pilot uses the CS to detect icing on the pitot tube.	Pass	Met or exceeded expected results	Pass	Pilot would notice airspeed problems if pitot tube blocked by ice	Not Observed	Met or exceeded expected results.	Pass		Pass
14a-8-2	Determine if the UA has structural ice.	Pilot uses the payload video to inspect the UA for structural icing.	Pass	Met or exceeded expected results	Pass	Possible with the use of payload. No payload operator used.	Not Observed	Met or exceeded expected results.	Pass		Pass
14a-9	Monitor aircraft electrical, propulsion, and datalink performance.	Pilot monitors status and health of electrical, propulsion, and datalink systems.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14a-9-1	Determine if current bus voltage is within limitations.	Pilot monitors bus voltage and determine it is within the POH-required limits.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Auto and # display	Pass
14b-1	Monitor aircraft's position throughout the flight and	Pilot determines the location of the UA on a	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded	Pass		Pass

	maintain course in accordance with ATC instructions/clearance.	location display.						expected results.			
14b-1-1	Determine current location	Pilot determines current location on the location display and/ or GPS coordinate display.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-1-1	Turn and maintain 130 degrees.	Pilot turns from 360 degrees to 130 degrees.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-2	Intercept and track a given course, radial (if equipped), or bearing, as appropriate.	Pilot plots a course and command the UA heading.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	GPS Pt to PT only. Pilot could calculate equivalent radial intercept with VOR position information.	N/A
14b-2-1	Determine the course heading to Nashville, TN.	Pilot plots a course heading from the UA's current position direct to Atlanta, GA. While factoring winds.	Pass	Met or exceeded expected results	Pass	Different location used; same outcome achieved	Pass	Met or exceeded expected results.	Pass		Pass
14b-2-2	Determine a ground track to Nashville, TN.	Pilot determines a ground track necessary for a direct course to Atlanta, GA.	Pass	Met or exceeded expected results	Pass	Different location used; same outcome achieved	Pass	Met or exceeded expected results.	Pass		Pass
14b-3	Determine loss of GPS or navigation solution if it occurs.	The pilot interprets the GPS health and status within the CS.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	WCA with secondary menus display for more detail information	Pass
14b-4	Maintain the appropriate altitude and headings.	Pilot turns the UA and change altitude while in flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-4-1	Turn to heading 350 degrees.	Pilot turns the UA to 350 degrees magnetic.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-4-2	Climb and maintain 10,000 feet MSL.	Pilot climbs the UA to 10,000 MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Used 5,000 ft	Pass
14b-4-3	Perform dead reckoning navigation if required.	Pilot uses payload video to navigate back to a landing airport.	Pass	Met or exceeded expected results	Pass	No payload operator	Pass	Met or exceeded expected results.	Pass		Pass

14b-4-4	Return to Huntsville International Airport via heading and airspeed.	Pilot uses the UA's heading and ground speed to return to HSV.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-4-6	Use payload video to enter the traffic pattern at Huntsville International Airport.	Pilot uses payload video to navigate into the traffic pattern.	Pass	Met or exceeded expected results	Pass	No payload operator	Not Observed	Met or exceeded expected results.	Pass		Pass
14b-6	Maintain course by reference to established waypoints/steer points or other navigational references, as applicable.	Pilot remains on an established course and changes course once waypoints are achieved.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-7	If equipped, be able to identify surface features to chart symbols.	Pilot performs map to video correlation between the payload video and location display to identify natural and man-made terrain features.	Pass	Met or exceeded expected results	Pass	No payload operator	Not Observed	Met or exceeded expected results.	Pass		N/E
14b-8	Navigate by means of precomputed headings, groundspeeds, and elapsed time (if required).	Pilot determines a required heading +/- 10 degrees, groundspeed +/- 10 knots, and time +/- 3 minutes.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Manual calculation from provided data	Pass
14b-9	Correct for wind to maintain desired route and performance.	The Pilot acknowledges and corrects for wind to maintain desired course.	Pass	Met or exceeded expected results	Pass	This is an automated process in point navigation	Pass	Met or exceeded expected results.	Pass		Pass
14b-10	Remain within planned route described in the flight plan.	The Pilot commands the UA to maintain the desired course, speed, and altitude outlined in the flight plan.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-1	Obtain ATC clearance.	Pilot performs two-way radio communication to obtain an ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-2	Request clearance for transitioning into R-2104B	Pilot performs two-way radio communication to request clearance into R-2104B restricted airspace.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-3	Respond to ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-4	Cleared into R-2104B airspace. Maintain climb	Pilot reads back the ATC clearance approval using	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded	Pass		Pass

	and maintain 5,000 feet MSL.	standard aviation terminology.						expected results.			
14b-10-5	Comply with ATC clearance.	Pilot maneuvers the UA to comply with ATC clearance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
14b-10-6	Cleared into R-2104B airspace. Maintain climb and maintain 5,000 feet MSL.	Pilot turns the UA into R2104B, remain within that airspace, climb to 5,000 feet MSL and level off.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Used simulated airspace	Pass
18-1	Monitor UAS fuel/battery status while in flight.	The pilot monitors UAS fuel/battery status while in flight	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-2	Adjust power settings as required to maintain desired performance.	The pilot adjusts power settings as required to maintain desired performance.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass	Set indirectly by selecting airspeed, and /or altitude change commands	Pass
18-3	Perform fuel burn/battery consumption calculations such that the destination is reached with the required fuel reserve/battery power remaining.	The pilot demonstrates the knowledge to perform fuel burn/battery consumption calculations such that the destination is reached with the required fuel/battery life. reserve/battery power remaining.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-4	Re-evaluate performance data as required to reach the destination at the required time with the required fuel/battery reserves.	The pilot demonstrates the knowledge to re-evaluate performance data as required to reach the destination at the required time with the required fuel/battery reserves.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
18-5	Determine any new performance capabilities or limitations that may result from alterations in the flight plan or an in-flight emergency.	The pilot determines any new performance capabilities or limitations that may result from alterations in the flight plan or an in-flight emergency.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
19-1	Monitor weather conditions along the route of flight, establishing communications with in-	The pilot uses any available means to demonstrate the ability to monitor weather	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

	flight weather services as required.	conditions along the route of flight, establishing communications with in-flight weather services as required.									
19-2	Determine if icing conditions exist and utilize anti/de-icing equipment as appropriate.	The pilot uses any available means to demonstrate the ability to determine if icing conditions exist and utilize anti/de-icing equipment as appropriate.	Pass	Met or exceeded expected results	Pass	Not intended for flight into known icing; No payload operator	Not Observed	Met or exceeded expected results.	Pass	No Payload cameras.	N/E
19-3	When necessary, alter the flight plan to avoid weather that poses a hazard to the safety of flight.	The pilot demonstrates proper situation awareness and (when necessary), alter the flight plan to avoid weather that poses a hazard to the safety of flight.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
19-4	Notify ATC if a flight plan must be altered to avoid hazardous weather.	The pilot uses any available means to notify ATC if a flight plan must be altered to avoid hazardous weather.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
30-1	Receiving Pilot - Perform preflight on receiving GCS and verify correct function of essential systems.	The pilot performs preflight on receiving GCS and verifies correct function of essential systems.	Pass	Not capable on simulator.	Not observed	Documented in a preset procedure	Pass	Met or exceeded expected results.	Pass		Pass
30-2	Establish two-way communication with the receiving control station prior to initiating a control station handoff.	The pilot establishes two-way communication with the receiving control station prior to initiating a control station handoff.	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass		Pass
30-3	Receiving CS: Coordinate with transferring CS to establish C2 link with UA, if/as applicable per the pilot's operating handbook (POH).	The receiving CS coordinates with the transferring CS to establish C2 link with UA, if/as applicable per the pilot's operating handbook (POH).	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass		Pass
30-4	Receiving CS: Coordinate with transferring CS to establish C2 link with UA, if/as applicable per POH.	The Receiving CS coordinates with Transferring CS to establish C2 link with UA, if/as applicable per POH.	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass		Pass

30-5	Transferring CS: Provide handover briefing to Receiving CS: - Verify autopilot mode - Verify matched commands (if applicable) - Verify data terminal settings (if applicable) - Verify altimeter setting - Verify current clearance - Verify any other flight-critical systems	The Transferring CS pilot provides handover briefing to Receiving CS pilot: - Verify autopilot mode - Verify matched commands (if applicable) - Verify data terminal settings (if applicable) - Verify altimeter setting - Verify current clearance - Verify any other flight-critical systems	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass	These are automatically downloaded to CS from UA when receiving RPIC connects	Pass
30-6	Transferring CS: Positive transfer of UA control to Receiving CS.	The Transferring CS pilot verifies positive transfer of UA control to Receiving CS.	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass		Pass
30-7	Receiving CS: Verify UA control.	The Receiving CS pilot is able to verify UA control.	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass		Pass
30-8	Keep the transferring on link as backup, if/as applicable.	Pilot ensures that the transferring CS remains on link as backup. If/as applicable.	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass		Pass
30-9	For transfer of UA control from one CS to another - Perform a control station handoff briefing for the receiving pilot, to include at a minimum: - UAS overall health - Fuel/battery state - Altitude - Altimeter setting - Airspeed - Heading - ATC clearances - Any abnormal occurrences - Contingency/emergency plan(s) - Safety critical information that the receiving pilot will need to ensure safe flight - confirmation of command link integrity (strength/ reliability)	For CS internal handoff – The pilot performs a control station handoff briefing for the receiving pilot, to include at a minimum: - UAS overall health - Fuel/battery state - Altitude - Altimeter setting - Airspeed - Heading - ATC clearances - Any abnormal occurrences - Contingency/emergency plan(s) - Safety critical information that the receiving pilot will need to ensure safe flight - confirmation of command link integrity (strength/ reliability)	Pass	Not capable on simulator.	Not observed		Pass	Met or exceeded expected results.	Pass	These are automatically downloaded to CS from UA when receiving RPIC connects	Pass

30-10	For an internal crew changeover within a CS – Perform a crew changeover briefing for the receiving pilot, to include at a minimum: - UAS overall health - Fuel/battery state - Altitude - Altimeter setting - Airspeed - Heading - ATC clearances - Any abnormal occurrences - Contingency/emergency plan(s) - Safety critical information that the receiving pilot will need to ensure safe flight - confirmation of command link integrity (strength/ reliability)	For an internal crew changeover - The pilot is able to perform a crew changeover briefing to the receiving pilot, to include at a minimum: - UAS overall health - Fuel/battery state - Altitude - Altimeter setting - Airspeed - Heading - ATC clearances - Any abnormal occurrences - Contingency/emergency plan(s) - Safety critical information that the receiving pilot will need to ensure safe flight - confirmation of command link integrity (strength/ reliability)	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

Flight Card Description	Flight Test #13	Test Case Description	Perform In-Flight Emergencies and Abnormal Operating Procedures		
Validation Attempt ID	All	Data Collector ID	Collective	UAS Operator ID	All
Researcher/Assessor's ID	All	Date Tested	June 6, 2017	Test Case (Pass/Fail)	N/A

Assumption #	Assumptions:
1	UGCS operating in simulation mode
2	Platform-specific POH is available in CS
7	UA is airborne
8	A simulated ATC entity is available

OP #	Operational Procedures Validated
38	In-Flight Emergencies - Detect and Avoid
46	Abnormal Operating Procedures - General

			Final Result	Observer 1	Observer 1	Observer 2	Observer 2	Observer 3	Observer 3	Observer 4	Observer 4
OP #	**Operational Procedure/ Process Step**	**Expected Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**	**Actual Results**	**Pass / Fail / Not Observed/ Not Applicable / Suspended**
38-1	Abide by applicable right-of-way rules.	The pilot abides by applicable right-of-way rules.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass
38-2	When applicable, use available collision avoidance instruments and understand their associated procedures.	The pilot demonstrates knowledge of applicable collision avoidance instruments and demonstrate knowledge of the applicable collision avoidance procedures.	N/A	Not capable with simulator.	Not observed.	No DAA equipment installed	N/A	Met or exceeded expected results.	Pass		N/A
38-3	If an automated detect and avoid system is used, it must give way to other air traffic in a manner that is consistent with 14 CFR 91.113.	The pilot monitors the automated detect and avoid system (if used) and ensure that the automated detect and avoid system commands an avoidance maneuver consistent with 14 CFR 91.113.	N/A	Not capable with simulator.	Not observed.	No DAA equipment installed	N/A	Met or exceeded expected results.	Pass		N/A
38-4	Monitor DAA system to maintain safe distance from other aircraft.	The pilot monitors the DAA system (if used) and ensure that the DAA system maintains safe distance from other aircraft.	N/A	Not capable with simulator.	Not observed.	No DAA equipment installed	N/A	Met or exceeded expected results.	Pass		N/A
38-5	Execute evasive maneuvers when required.	The pilot uses the CS to execute evasive maneuvers when	N/A	Not capable with simulator.	Not observed.	No DAA equipment installed	N/A	Met or exceeded expected	Pass		N/A

		required.						results.			
38-6	When applicable, the pilot must monitor the execution of automated collision avoidance maneuvers.	When applicable, the pilot uses the CS to monitor the execution of automated collision avoidance maneuvers.	N/A	Not capable with simulator.	Not observed.	No DAA equipment installed	N/A	Met or exceeded expected results.	Pass		N/A
38-7	Override autonomous DAA system, if required.	If required, the pilot demonstrates the capability to use the CS to override autonomous DAA system.	N/A	Not capable with simulator.	Not observed.	No DAA equipment installed	N/A	Met or exceeded expected results.	Pass		N/A
38-8	Notify ATC of intentions when able.	The pilot notifies ATC of intentions when able	N/A	Not capable with simulator.	Not observed.		Pass	Met or exceeded expected results.	Pass		N/A
46-1	Perform any abnormal operations procedures as they are published for the given system.	The pilot is performs any abnormal operations procedures as they are published for the given system.	Pass	Not capable with simulator.	Not observed.	No documented abnormal procedures	N/A	Met or exceeded expected results.	Pass		N/A
46-2	Report any failures of instrumentation, reversion to backup or standby systems, or any other failure/abnormal operation that may impact safety of flight to ATC.	The pilot reports any failures of instrumentation, reversion to backup or standby systems, or any other failure/abnormal operation that may impact safety of flight to ATC.	Pass	Met or exceeded expected results	Pass		Pass	Met or exceeded expected results.	Pass		Pass

APPENDIX E—VALIDATION RESULTS

The validation process during research task PC-3 demonstrated procedures from the operational requirements identified in research phases PC-1 and PC-2. Not all operational requirements or procedures were validated using the UGCS because they were independent of control stations. These requirements or procedures were compared to reasonableness during PC-1 consisting of manned and unmanned aircraft requirements and procedures. PC-1 analyzed these requirements and recommended procedures from multiple sources, including federal aviation regulations, Airplane Flight Manuals (AFM) and Pilots Operating Handbooks (POH). Additionally, by comparing a common set of UAS tasks to various representative UAS platforms' procedures commonality was determined. These requirements and procedures were also compared to manned tasks as given by the FAA Commercial Practical Test Standards (PTS) and the Airman Certification Standards (ACS) for a typical single-engine airplane (C-172). Relevant tasks from the Instrument ACS were considered for comparison as appropriate.

The recommended minimum operational requirements and procedures focused on high-level requirements for UAS pilots such as roles and responsibilities, duty requirements, rest requirements, and minimum requirements served by the role of PIC. Minimum operational requirements and procedures related to flight operations were also contained within this section, organized by phase of flight. Since they were foundational in nature, they formed the basis for addressing all operational scenarios, from normal flight operations, to emergency, and abnormal scenarios. The intent with these requirements and procedures was to provide minimum recommended procedures to the FAA. Recommended requirements and procedures for additional crewmembers, such as crew chiefs, visual observers (VOs), and other essential crew were not included in this document.

Table 3. Non-Validated Procedures.

Pilot Procedure	Operational Procedure	Procedure Name	Validation Result Using UGCS
1		Requirements and Procedures Related to UAS Pilots	**Not Validated**
2		Pilot Duty Requirements	**Not Validated**
3		Pilot Rest Requirements	**Not Validated**
4		Minimum Flight Crew	**Not Validated**
	1	Before Entering GCS	**Not Validated**

Table 4. Validated Procedures.

Pilot Procedure	Operational Procedure	Procedure Name	Validation Result Using UGCS
	2	Presets	**Pass**
	3	Pre-Flight	**Pass**
	4	Engine Start	**Pass**
	5	Pre-Taxi	**Pass**
	6	Taxi - General	**Pass**
	7	Taxi - Communications	**Pass**
	8	Pre-Takeoff Checks	**Pass**
	9	Takeoff Communications	**Pass**
	10	Takeoff Run/ Launch	**Pass**
	11	Initial Climb Out	**Pass**
	12	Aborted Takeoff	**Pass**
	13	Climb to Altitude - General	**Pass**
	14a	En-route Operations - General	**Pass**
	14b	En-route Operations - Navigation	**Pass**
	15	En-route Operations - Climb	**Pass**
	16	En-route Operations - Course Change	**Pass**
	17	En-route Operations - Descents	**Pass**
	18	Cruise Power Settings	**Pass**
	19	Weather Monitoring	**Pass**
	20	Descent From Cruise - General	**Pass**
	21	Approach - General	**Pass**
	22	Landing - Communications	**Pass**
	23	Approach and Landing - (Human in the Loop)	**Pass**
	24	Go Arounds	**Pass**
	25	Ground Support	**Pass**
	26	Approach and Landing (Automated)	**Pass**
	27	Post-Landing - Communications	**Pass**
	28	Post-Landing - Taxi	**Pass**
	29	Post-Landing - Ground Support	**Pass**
	30	Control Station Handoff - General	**Pass**
	31	Lost-Link Control Procedures - General	**Pass**
	32	Lost-Link Troubleshooting Procedures - General	**Pass**
	33	Operations During Command and Control Degradation and Loss - General	**Pass**
	34	Operations During Periods of Decreased Sensory Cues from Aircraft and Environment	**Pass**
	35	In-Flight Emergencies - Propulsion Failure	**Pass**

	36	In-Flight Emergencies - Two-way Communications Failure	**Pass**
	37	In-Flight Emergencies - Navigation Failure - GPS or Other System	**Pass**
	38	In-Flight Emergencies - Detect and Avoid	**Pass**
	39	In-Flight Emergencies -Uncontrolled Flight	**Pass**
	40	In-Flight Emergencies - Emergency Descent	**Pass**
	41	Emergency Landing - Communication	**Pass**
	42	Emergency Landing - Approach	**Pass**
	43	Emergency Landing - Touchdown	**Pass**
	44	Emergency Landing - Ditching Site Selection	**Pass**
	45	Emergency Landing - Flight Termination	**Pass**
	46	Abnormal Operating Procedures - General	**Pass**