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ASSURE UAS Research and Development Program Research Abstract
FAA Research Requirement: UAS Maintenance, Modification, Repair, Inspection, Training, and Certification Considerations **UAS Research Focus Area:** UAS Crew Training and Certification

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ASSURE External Advisory Board Principle Investigator (if applicable): N/A
Other ASSURE External Advisory Board (EAB) Performers (if applicable): N/A
Classified or Security Related Work: No

EXECUTIVE SUMMARY:

Kansas State University (KSU) is proposing research to identify the requirements and considerations for UAS maintenance, modification, repair, inspection, training, and certification by building upon the existing body of knowledge for sustaining UAS. The proposed research involves collecting and consolidating current UAS practices from industry and developing new requirements to ensure that risks of maintenance-induced failures are minimized. The research team will add to prior work completed by the FAA which created a prototype Maintenance & Repair (M&R) database.

The tasks outlined in this proposal will be completed cooperatively utilizing the UAS maintenance resources at KSU, ATC simulation capabilities of Embry-Riddle Aeronautical University (ERAU), and composite repair specialties at Montana State University (MSU). The key components of this research include: 1) review existing data available for maintaining UAS of all sizes, 2) compare existing maintenance data for UAS with the type of data available for manned aircraft, 3) determine if a delineation between different types/sizes of UAS is needed to establish varying thresholds of maintenance rigor, 4) identify best practices for maintaining various classes of UAS within the context of their operational environment, 5) compile the current training materials and qualifications required for various UAS platforms, and 6) recommend training and certification requirements for UAS maintenance technicians and repair stations across the spectrum of all UAS classes. All of these research components will build upon prior research to develop solid, justifiable recommendations to the FAA on how UAS should be maintained to support the FAA's roadmap to integration of UAS into the NAS.

1.0 Background

The FAA Modernization and Reform Act of 2012 (FMRA) mandates integration of UAS into the National Airspace System (NAS) no later than September 30, 2015. In today's NAS environment, as the roles and uses of UAS are evolving at an ever-increasing rate, which is expected to continue as the FAA implements NextGen, the FAA is challenged to keep up with the demands of airspace access from the UAS community. Most of the challenges to integration reside in the context of unmanned aircraft meeting applicable regulations, as UAS are currently primarily designed for specific operational mission environments and typically do not conform to the same standards as manned aircraft. However, at present, there is a known gap that exists between the design, certification, and continued airworthiness standards for manned aircraft and those for UAS. Most UAS are composed of modular systems, commercial-off-the-shelf (COTS) parts, and other replaceable/repairable components. In addition, they usually feature ground support equipment; The equipment is just as critical to the performance and safety of the UAS as the UAS airframe.

The focus on UAS maintenance training programs has emerged as a high priority in the UAS Integration Office, due to the change in direction from the FAA coupled with the congressional mandate to accomplish initial NAS Integration by 2015. UAS maintenance and repair research is critical in achieving the FAA's vision of safe, efficient, and timely integration of UAS in the NAS. In addition, it has been noted that the sponsoring office needs to address the growing concern of the UAS community towards integration by tackling aspects of UAS maintenance programs. A key aspect of these programs is that the UAS manufacturer typically assumes the role of a repair station, which is not permitted under Part 145. Furthermore, questions remain that must be answered in terms of continuous airworthiness, maintenance, and inspection issues, as well as requirements for dealing with the consequences of maintenance-induced failures in the NAS. This requirement has been discussed at the UAS TCRG and has the support of the UAS Integration Office and UAS TCRG Lead.

2.0 Scope

There is a significant lack of knowledge and understanding regarding the initial and continuing airworthiness of UAS and how it differs from manned aircraft. UAS are often fabricated from materials, such as foam or unique composites, that are not normally found in previously type certificated aircraft and have little to no documentation of sustainment considerations. There are components of UAS, such as ground control stations and communication links, that create new concerns for ensuring continued airworthiness. Additionally, the skill set required to effectively sustain a UAS may differ substantially from traditional aircraft maintenance technician skills. All of the above issues must be resolved to safely integrate UAS into the National Airspace System with the same level of safety assurance that currently exists.

The purpose of this research is to identify the maintenance, modification, repair, inspection, training, and certification (hereafter shortened to "maintenance" as a collective term) considerations that are necessary to ensure continued airworthiness of UAS. Part of this process is to determine the current state in the industry of UAS maintenance practices and determine if that state is adequate to ensure the safe operation of the systems in a complex airspace environment. If the current state of the industry's maintenance practices is found to be lacking, then there is a need to identify the gaps between current and ideal states and propose solutions for filling these gaps.

This research will consider all of the prior research on this topic and investigate the unique aspects of UAS maintenance at great length.

The key components of this research include: 1) review existing data available for maintaining UAS of all sizes, 2) compare existing maintenance data for UAS with the type of data available for manned aircraft, 3) determine if a delineation between different types/sizes of UAS is needed to establish varying thresholds of maintenance rigor, 4) identify best practices for maintaining various classes of UAS within the context of their operational environment, 5) compile the current training materials and qualifications required for various UAS platforms, and 6) recommend training and certification requirements for UAS maintenance technicians and repair stations across the spectrum of all UAS classes. All of these research components will build upon prior research to develop solid, justifiable recommendations to the FAA on how UAS should be maintained to support the FAA's roadmap to integration of UAS into the NAS.

The primary research questions being answered through this research are:
1. What is the current state of UAS maintenance practices and training throughout the industry?
2. How does the current state of UAS maintenance practices and training compare to manned aviation practices?
3. What are the elements that comprise UAS maintenance for all types/sizes of UAS?
4. What are the unique elements of UAS maintenance that differ from manned aircraft maintenance and what is their implication on training and certification?
5. What are the unique considerations for composite material structures of UAS?
6. Is there a need to delineate between different risk classes of UAS when determining maintenance and training requirements?
7. What are the consequences of maintenance-induced failures in UAS?
8. What standards exist, or need to be developed, for determining requirements and capabilities of entities that modify and/or repair UAS?

3.0 Research Framework

3.1 Research Requirement.

1. Review of Existing Data

The researchers will conduct a review of existing data available for maintaining UAS of all sizes. This review will include data such as maintenance, repair, and inspection on multiple UAS manufacturers/operators for various types/sizes of UAS and requirements. This data will be used to update the M&R prototype database described in Task 2.

Additionally, a literature review will be performed to uncover previous research for UAS maintenance considerations, such as Dr. Alan Hobbs' work at NASA Ames. This detailed review of the current body of knowledge for UAS maintenance practices will ensure that the work completed under this research effort are building upon prior research and not replicating existing findings.

2. Update M&R Prototype Database

Following maintenance, repair, and inspection data collection in Task 1, the prototype database will be updated to include additional functionality and incorporate preliminary analysis tools based upon the Technical Sponsor's priorities and feedback. With additional datasets added to the database, it is expected that new analytical tools will be able to extract increasingly useful information from the data and reveal trends across the industry and over time. The database will be updated throughout the life of the project as new maintenance data is collected. It is expected that some maintenance procedures, especially for aircraft commonly used by the Department of Defense, may contain sensitive information that will need to be sufficiently redacted/generalized in order to protect proprietary or national security concerns.

3. Review Maintenance Technician Training

Industry standards and best practices for maintenance of UAS, such as ASTM F2909-14 will be reviewed. Training programs with qualifications/skill requirements will be documented for UAS maintenance technicians of all types/sizes of UAS. Interviews will be conducted with maintenance technicians across the spectrum of size and types in order to determine if there are trends in the significant challenges faced by technicians. Other means of extracting this data will be considered, such as a survey or questionnaire, or through focus groups.

4. Develop Maintenance Technician Training Certification Requirements

The certification requirements for UAS maintenance technicians will be developed after an in-depth study of the current body of knowledge on UAS maintenance throughout the industry, academia, and government. There are several areas that the researchers expect will require significant study in order to develop the proper certification requirements as they differ from manned aircraft substantially. These areas include, but may not be limited to:

a) Composite material structures
b) Ground control stations and support equipment
c) Communication links
d) Software and autopilot

For the areas described above, the researchers propose to perform in-depth analysis of the tasks themselves, skills required, current training techniques, and industry best practices. For example, composite material structures will be studied by:

a) Performing a survey of the typical materials, repair, and inspection procedures for composites on large and small UAS
b) Reviewing the existing standards for repair of composite material structures and assess the applicability of standards such as those developed by the Commercial Aircraft Composites Repair Committee (CACRC)

c) Perform trial repairs on a wide variety of materials using different methods to determine the airworthiness of such repairs and provided to FAA and its designees for review

d) Recommendations on the certification criteria for UAS maintenance technicians for composites repair will be incorporated into the overall criteria developed throughout this project

The final recommendations for UAS maintenance technician certification requirements will be based firmly on the established protocol for manned aircraft while considering the unique nature of unmanned systems and allowing for growth and modification of the requirements as this technology evolves. It is important that any recommendations developing from this research are able to remain relevant with the ever-changing UAS technology and expansion of capability while also ensuring that the level of rigor is appropriate for the risk incurred by the failure of the systems being studied. For this reason, the researchers will consider if there is justification to delineate maintenance technician certification requirements between different classes of aircraft based on their risk. Any delineation of requirements will be collaboratively developed with cooperation from the technical sponsor in order to ensure alignment with other potential groupings of risk classes for unmanned systems currently being proposed within the FAA.

5. Conduct Simulations Focused on UAS-ATC Procedures

Simulations will be conducted by the research team to understand the nature of maintenance-induced failures on the UAS-ATC environment. Procedures and consequences of dealing with maintenance-induced failures and emergencies will be evaluated. The type of failure(s) will be defined after a review of the accident/incident database for UAS failures and through interviews with appropriate subject matter experts. Collaboration between ERAU UAS training faculty in the BS in Unmanned Aircraft Systems Sciences and faculty in the Aviation Maintenance Sciences program will support this effort through the simulation of maintenance-induced failures and their impact on UAS-ATC procedures. First, simulation protocols shall be developed involving typical UAS scenarios in which a maintenance-induced failure would impact UAS operations in controlled airspace. Second, UAS faculty and staff will develop the simulation scenarios for execution in the ERAU UAS Simulation Laboratory, which is equipped with 16 UAS pilot-crew workstations and capable of simulating various system faults. Third, trained UAS operators shall execute the scenarios. Lessons learned regarding UAS operations, ATC procedures, and the impact of maintenance-induced failure will be documented and reported.

6. Support UAS Certification Efforts, ASI Training, and Repair Station Criteria

The data collected throughout the duration of this project will be used by the project team to inform the initial airworthiness certification processes currently under development within the Small Airplane Directorate (ACE-100) and the Rotorcraft Directorate (ASW-100). The performers are currently engaged with the Small Airplane Directorate on a separate project (ASTM Standards Validation Project) with existing relationships and lines of communication that will assist in flowing the data and knowledge derived from this task

directly to the responsible directorates. Additionally, the same flow of information will be established with the appropriate entities for training Aviation Safety Inspectors (ASI).

Part of this subtask will include the development of criteria for UAS repair stations. 14 CFR 145 will be reviewed in context with the maintenance requirements for UAS to determine the applicability of current regulations to unmanned maintenance and repair. The project team will then develop proposed criteria for UAS repair stations based on the results of this review and a subsequent gap analysis of 14 CFR 145 as applied to UAS.

7. Examine Requirements for Maintenance-Related Accident Reporting

The current requirements for data collection and reporting of UAS accidents/incidents will be reviewed to determine their effectiveness and likelihood of capturing significant ongoing issues. A recommendation will be provided to the technical sponsor regarding improvements to the collection and reporting requirements that are needed to ensure that events are captured in sufficient detail, in a timely manner, and enough data is provided to inform the FAA on potential action to prevent further occurrences of the events.

8. Final Report

A final report for documenting the project shall be submitted including applicable data, analysis and findings from the project. The report will include:

1. UAS Maintenance Data & Collection Criteria for UAS maintenance, repair, and inspection programs from participating manufacturers/operators.
2. UAS Maintenance Program Review
3. UAS Maintenance Data Preliminary Analysis
4. UAS Maintenance Technician Training Criteria & Certification Requirements
5. UAS Maintenance Simulation Activity
6. UAS Repair Station Criteria
7. UAS Accidents/Incidents Data Recording

3.2. Research Mapping.
This research will support the following FAA initiatives:
a) Work requested by the FAA via Statement of Work for FY15 UAS COE Requirements Review Package.
b) Informs work being performed by ASTM F38 Committee on UAS to establish consensus standards for maintenance of small UAS.
c) Informs ongoing efforts within ACE-100 and ASW-100 for type certification of UAS.

3.3 Research Review.
The performers are aware that previous research exists on the maintenance requirements and considerations for UAS. Work performed by NASA Ames (human factors issues in UAS maintenance) and FAA (small UAS maintenance and repair) has addressed several key challenges for maintaining unmanned systems. The performers will conduct a detailed literature review of UAS maintenance considerations research across the globe. Work ongoing or previously conducted by other civil and military aviation authorities will be reviewed and

analyzed. A literature review document will be provided to the technical sponsor upon completion of this step.

4.0 Research Approach and Outcomes

The research task plan, outcomes, and spending are proposed in the following table. The level of effort and estimated costs are further broken down by performer in section 8.0.

Task	Proposed Outcomes	Date Due	ASSURE Performer
1. Review of Existing Data	Draft technical report of the UAS Maintenance Data	T + 3 months	KSU ERAU
	Draft technical report of UAS Maintenance Data Preliminary Analysis	T + 6 months	KSU ERAU
2. Update M&R Prototype Database	Updated database with analytical tools	T + 9 months	KSU
3. Review Maintenance Technician Training	Survey Results	T + 9 months	KSU
	Technical review/report of UAS Maintenance Technician Training Standards		
4. Develop Maintenance Technician Training Certification Requirements	Draft technical report of UAS Maintenance Technician Training Criteria & Draft Certification Requirements	T + 15 months	KSU MontSU ERAU
5. Conduct Simulation(s) Focused on UAS-ATC Procedures	UAS Maintenance Simulation Activity Presentation	T + 18 months	ERAU
6. Support UAS Certification Efforts and ASI Training; Develop Repair Station Criteria	Draft technical report of UAS Repair Station Criteria	T + 18 months	KSU ERAU
7. Examine Requirements for Maintenance-related Accident Reporting	Draft technical report of UAS Accidents/Incidents Data Recording List	T + 18 months	ERAU
8. Final Report	Final report compiling all reports research tasks	T + 18 months	KSU
Research Task Plan	Description of research plan, including detailed schedule	T + 1 months	KSU
Quarterly Status Reports	Quarterly reports addressing the status of the research deliverables, schedule, budget, and risks.	Quarterly	KSU
Technical Interchange Meetings (TIMs)	Notes capturing discussions and action items from each TIM. This task budget includes travel expenses.	3 days after the TIM	KSU MontSU ERAU
		Total	

5.0 Government Furnished Information

The government will furnish the following information to the performer:
   a) A11L.UAS.03.1 (UAS-11-05) UAS Maintenance and Repair Tracking System final report
   b) UAS M&R prototype database
   c) Latest revisions of draft Advisory Circular for *Design Standards and Assumptions for Type Design Approval Under 14 CFR 21.17(b) of Fixed Wing Unmanned Aircraft Systems (UAS)* and its rotor wing equivalent, if such exists or is developed during the period of performance
   d) Other pertinent draft and approved documents related to UAS certification and maintenance as determined by the research team

6.0 Period of Performance/Projected Schedule

The following table outlines the proposed schedule for this project. The technical period of performance for this task order is **18** months.

Task	FY16				FY17	
	4Q CY15	1Q CY16	2Q CY16	3Q CY16	4Q CY16	1Q CY17
Research Task Plan	■					
1. Review of Existing Data	■	■				
2. Update M&R Prototype Database		■	■			
3. Review Maintenance Technician Training			■	■		
4. Develop Maintenance Technician Training Certification Requirements	▓	▓	▓	▓		
5. Conduct Simulation(s) Focused on UAS-ATC Procedures	E	E	E	E	E	E
6. Support UAS Certification Efforts and ASI Training; Repair Station Criteria					■	■
7. Examine Requirements for Maintenance-related Accident Reporting	E	E	E	E	E	E
8. Final Report						■

7.0 List of Universities and Individuals Involved in the Project

Kansas State University
- Mark Blanks, UAS Program Manager, Applied Aviation Research Center
- Stephen Ley, Aviation Maintenance Program Lead, Department of Aviation
- Michael Most, UAS Academic Program Lead, Department of Aviation
- Richard Brown, Lead UAS Technician, Applied Aviation Research Center

Montana State University
- Doug Cairns, Professor, Mechanical & Industrial Engineering

Embry-Riddle Aeronautical University
- John Robbins, Assistant Professor, Department of Aeronautical Science
- Mitch Geraci, Assistant Professor, Department of Aeronautical Maintenance Science

8.0 Estimated Level of Effort and Associated Costs

Performer: Kansas State University		
Year	**Performance Period**	
FY16	12 months	Task plan; Tasks 1, 2, 3, 4; Travel
FY17	6 months	Tasks 4, 6, 8; Travel
Total	**18 months**	

Performer: Montana State University		
Year	**Performance Period**	
FY16	12 months	Task 4; Travel
Total	**12 months**	

Performer: Embry-Riddle Aeronautical University		
Year	**Performance Period**	
FY16	12 months	Tasks 1, 2, 4, 5, 6, 7; Travel
FY17	6 months	Tasks 5, 6, 7; Travel
Total		