NC STATE UNIVERSITY

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

ASSURE UAS Research and Development Program Research Abstract
FAA Research Requirement: A11LUAS.9_Surveillance Criticality for SAA **UAS Research Focus Area:** Low Altitude Operations Safety- Dept of Interior
FAA Management Team: UAS COE PM: Sabrina Saunders-Hodge, ANG-C2 UAS COE Dep. PM: Paul Rumberger, ANG-C2 Research Sponsor: Chris Swider, AFS-88 Research Sponsor Subject Matter Expert/Task Monitor: Paul Campbell, AFS-88 Task Program Manager: William Oehlschlager, ANG-C21
ASSURE Principal Investigator (PI): Kyle Snyder, NGAT Program Director, NC State University, ktsnyder@ncsu.edu
Other ASSURE Performers PI's: • Embry Riddle: Mohammad Moallemi • University of North Dakota: Will Semke, • Mississippi State University: Ratan Jha, • Ohio State University: Jim Gregory, • Oregon State University: Michael Wing, AIS Laboratory Director and Associate Professor,
ASSURE External Advisory Board Principle Investigator (if applicable): N/A
Other ASSURE External Advisory Board (EAB) Performers:
Classified or Security Related Work: No

EXECUTIVE SUMMARY:

Unmanned Aircraft Systems (UAS) integration will be successful when UAS operations meet an acceptable level of safety performance. Today that level is expected to be equivalent to the level of safety of manned aircraft. One criteria for evaluating that equivalency level is the ability for unmanned aircraft to Sense and Avoid (SAA) other aircraft operating in the National Airspace System (NAS). The FAA, standards organizations, product developers, and researchers have prepared multiple safety cases for the integration of SAA technologies. However, there is no baseline set of metrics or criteria for characterizing the performance of these technologies as "acceptable" or for comparing against manned aircraft pilots.

This research proposal is designed to develop a safety assessment process to determine the key drivers of aircraft-based surveillance system performance requirements for the purpose of aircraft-based sense-and-avoid (ABSAA) capability for UAS. The research team will assess the contributions of pilots and controllers in aircraft separation assurance and collision avoidance, and determine the potential safety impacts (both positive and negative) caused by pilots not being onboard the aircraft. This assessment will be used in an operational UAS Concept of Operations (ConOps) to evaluate the potential hazards, failure modes, effects, and criticality of select ABSAA technologies. The research team will conduct at least two iterations of a system design, analysis, and testing to identify mitigation strategies and potential performance expectations. Operational workshops will be held to review the analysis and provide

opportunities for NAS stakeholders to be involved in data collection and analysis. The results of this research will be published in a Final Report documenting the research process, data collected, and analysis methods that produced the conclusions for use in future separation criteria standards and technology development.

Six universities from the ASSURE Alliance will participate on this project. North Carolina State University (NCSU) will lead the project focusing on the ConOps descriptions and Functional Hazard Assessment activities. Embry Riddle Aeronautical University (ERAU) will perform the system performance analysis with modeling and simulation support from the Next-generation Applied Research Lab. Mississippi State University (MSU) will lead the system characterization activities for the project to determine which sense and avoid technologies are to be evaluated and in which conditions and scenarios. The University of North Dakota (UND) will contribute to ConOps development and system characterization tasks. The Ohio State University (OHSt) will support ERAU with system performance analysis. Oregon State University (ORSt) will participate in ConOps development and functional hazards assessment research to provide past experience in infrequent flight conditions. Every school will participate in workshops, technical interchange meetings, and reporting activities throughout the project performance period.

1.0 Background

Research is needed to determine the metrics for evaluating the performance of surveillance equipment that provides separation services and situational awareness to airspace users, including both manned and unmanned aircraft operators. To achieve an acceptable level of safety for separation and collision avoidance, function and failure condition classifications of current and emerging technology solutions must be established. Performance criteria include evaluating the information exchange with the aircraft operator, any communications (including data reporting) with other airspace systems, such as ATC or other TCAS/ADS-B equipped aircraft, and hardware failure analysis. Developing these criteria are critical for airworthiness assessments that will support broader operational approval for UAS integration into the NAS and adoption of other new technologies that offer separation services and situational awareness.

2.0 Scope

This research will determine the metrics for evaluating Airborne Sense and Avoid (ABSAA) surveillance equipment intended to provide separation services and collision avoidance functions for unmanned aircraft operating in the NAS. These metrics will be used for comparing UAS solutions to manned aircraft operations, which are either pilot-centric or technology-centric sensing methods.

The main research questions being answered through this research are:

1) Can UAS Sense and Avoid functions be carried out by equipage standards using current surveillance equipment?
2) How should the current operational or technical performance requirements for ADS-B Out and/or transponders be changed (if at all) for UAS Sense and Avoid functions for a cooperative SAA solution based on ADS-B and/or transponders?

3) What is the baseline metric for evaluating "equivalent level of safety" of UAS against piloted-aircraft for SAA functions?

The primary research objectives to be accomplished during this projects are:

1) Assess the pilot-controller interaction to isolate failures and faults in surveillance equipment and its contribution to safety of flight in maintaining separation and preventing collisions between aircraft.
2) Identify how the pilot's role in an aircraft and ATC contributes to the safety of separation and collision avoidance and determine if procedural (e.g. separation standards) or design changes (e.g. performance or safety requirements) of existing procedures and/or equipment may fail to provide sufficient safety with respect to separation and collision avoidance for UAS.
3) Conduct a safety evaluation of separation and collision avoidance functions supported by airborne surveillance systems and equipment to identify operational (e.g. separation standards) or design standards shortcomings to meeting NAS safety objectives, including analysis of "all clear" definitions.
4) Propose mitigation strategies to compensate for the lack of a pilot in the aircraft.

3.0 Research Framework

3.1 Research Requirement.

To answer the research questions and accomplish the primary objectives of the Surveillance Criticality Research Project, a team of multiple universities and industry partners is assembled. This team will provide the data, the facilities, the prior knowledge, and the research skills necessary to discover the performance metrics desired and host the workshops that will produce the results needed for evaluating for SAA solutions.

The team has collaborated to define the research to be executed, committed the necessary expertise and resources to performing the research, and will be led by the ASSURE PI at NC State University. The following complete research will be executed in FY16:

Phase 1: Data Exchange

- Tasks 3.11, 3.12 from FAA draft Task Description.
- This project phase will run the entire duration of the project. This phase will start with the Kickoff Meeting to be followed by the Research Task Plan Review. Tasking against this Phase will also include the Technical Interchange Meetings throughout the performance of the project. 12 TIMs are anticipated in the initial project scope.
- Deliverables
    - Research Task Plan with updated budget and schedule
    - TIM Summaries
    - Final Report

Phase 2: Initial System Design and Testing

- Tasks 3.1, 3.2, 3.3, 3.4, 3.5 from FAA draft Technical Description
- During this Phase the team will:

- Develop the ConOps and scenarios for system testing and assumptions identification.
- Conduct a Literature Review.
- Conduct a system characterization to identify equipment for evaluation and performance criteria to be measured.
- Perform a Functional Hazard Assessment of identified equipment against the defined ConOps.
- Use simulations and analytics models to evaluate the performance of SAA solutions.
- Conduct the first Operational Workshop at NC State University to review preliminary results for hazards identification, performance measurements, and initial mitigation strategies. Workshop participants will include ASSURE COE members, industry partners, and additional airspace user stakeholders such as pilots, air traffic controllers, industry product providers, and RTCA SC-228 representatives..
- Prepare an Interim Report with research findings, results from the operational workshop, and the Literature Review summary.

- Deliverables
    - ConOps with assumptions
    - Interim Report

Phase 3: Revised System Design and Testing

- Tasks 3.6, 3.7, 3.8, 3.9 from FAA draft Technical Description
- During this Phase the team will:
    - Use the original ConOps and operational assumptions as identified in Phase 2.
    - Revise the system characterization to include equipment performance mitigation strategies and procedural changes for SAA functional requirements.
    - Perform a revised FHA of identified equipment with mitigations against the defined ConOps.
    - Use simulations and analytics models to evaluate the performance of the revised-SAA solutions.
    - Conduct the second Operational Workshop to review revised results for hazards identification, performance measurements, and the need for additional mitigation strategies.
- Deliverables:
    - Second Operational Workshop summary report

Phase 4: Final Revisions and Analysis

- Task 3.10 from FAA draft Technical Description
- During this Phase the team will:
    - Repeat an analysis or revise a specific mitigation solution for further analysis, based on results from the Phase 3 baseline safety analysis or the second Operational Workshop.
- Deliverables: None, unless an additional Operational Workshop is necessary.

3.2. Research Mapping.

1) Project specifically requested by the FAA via a Task Description for Surveillance Criticality Research.
2) Project will benefit from similar FAA research initiatives such as the current Pathfinder Project with Precision Hawk and the previous Limited Deployment – Cooperative Airspace Project (LD-CAP) with UND and MITRE. NextGen Program evaluations for ADS-B adoption and transitioning will also be evaluated by the research team.
3) ASSURE Industry Partners will provide research results and sample data sets from work supporting ADS-B network integration, DOD related SAA functional testing, and manned aircraft SAA performance evaluations. RTCA SC-228 representatives will also be included for mutual information sharing related to DAA and C2 MOPS.

3.3 Research Review.

A recent Literature Review will be conducted during Phase I of this project. The Literature Review will validate the need for research while also providing context for the scenarios and ConOps assumptions that will be used to generate the performance results.
The Literature Review will be included in the Interim Report.

3.4 Research Approach.

The research approach for this project is divided into 4 Phases with associated outcomes. Each university participating in each project Phase is identified in the following table.

Phase	Proposed Outcomes	Date Due
Phase 1: Data Exchange	Research Task Plan	T+1 month
	Meeting notes capturing the discussions and action items from each TIM.	monthly
	Final Report	T+12 months
Phase 2: Initial System Design and Testing	ConOps, test scenario descriptions with integrated system characterization descriptions	T+6 months
	Initial system modeling and simulation analysis	
	Operational Workshop #1	
	Interim Report	
Phase 3: Revised System Design and Testing	Revise system characterization descriptions for mitigation and including Workshop #1 feedback	T+10 months
	Revised system modeling and simulation analysis	

	Operational Workshop #2	
Phase 4: Final Revisions and Analysis	Revise system characterization descriptions for mitigation and including Workshop #2 feedback	T+12 months
	Revised system modeling and simulation analysis	
	Operational Workshop #3 (if necessary)	

T=Date of Award **Total**

4 Government Furnished Information

The government will furnish the following information to the performer:

a) UAS in the NAS Integration ConOps
b) ADS-B activity data and other flight track data sets that are potentially relevant, including live data feeds
c) UAS Test Site relevant data sets
d) Other reports and data discovered during Literature Review

5 Period of Performance/Projected Schedule

The technical period of performance for this task order is from the Date of Award (listed in table as T) for 12 months.

Task	**FY16**				**FY17**	
	4Q CY15	**1Q CY16**	**2Q CY16**	**3Q CY16**	**4Q CY16**	**1Q CY17**
Phase 1: Data Exchange						
Phase 2: Initial System Design and Testing						
Phase 3: Revised System Design and Testing						
Phase 4: Final Revisions and Analysis						

6 Proposed Outcomes

This section includes the schedule and a list of desired products. This needs to include:

Proposed Outcomes	Description	Date Due
Research Task Plan	NCSU: Description of research plan for the development and execution of the task. Shall include detailed schedule of the tasks to be executed as part of the project.	T+ 1
Technical Interchange Meeting (TIM)	ALL: Review progress via TELCON or Video Teleconference. Minimum monthly.	Monthly
Minutes/Notes	NCSU: Minutes/Notes capturing the discussions and action items form each Technical Interchange Meetings (TIMS)	3 days after the TIM
Quarterly Status Report	NCSU The report will provide the status of the research desired products, schedule, budget and risks.	Quarterly
Interim Technical Report	NCSU Preliminary research findings report to be completed after initial analysis and first Operational Workshop. Will include Literature Review, ConOps, and system assumptions.	T+6
Minutes/Notes	NCSU: Summary report from Second Operational Workshop.	3 days after the Workshop
Final Report	NCSU Final report, detailing safety performance metrics and procedural recommendations for meeting ABSAA objectives. Will also include suggestions for future research.	T+ 12 months

7 List of Universities and Individuals Involved in the Project

The following universities will participate on this project:

1. North Carolina State University
   a. PI: Kyle Snyder
2. Embry Riddle Aeronautical University
   a. PI: Mohammad Moallemi
3. University of North Dakota
   a. PI: Will Semke

4. Mississippi State University
    a. PI: Ratan Jha
5. The Ohio State University
    a. PI: Jim Gregory
6. Oregon State University
    a. PI: Michael Wing

8 Estimated Level of Effort and Associated Costs

This project is anticipated to be completed in 12 months.