A25: Develop Risk-Based Training and Standards for Waiver Review and Issuance

Final Report

12/17/2021

NOTICE

LEGAL DISCLAIMER

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-xx/xx		

4. Title and Subtitle

TITLE OF REPORT

A25: Develop Risk-Based Training and Standards for Waiver Review and Issuance: Final Report

5. Report Date

December 31, 2021

6. Performing Organization Code

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10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

U.S. Department of Transportation
Federal Aviation Administration
Washington, DC 20591

13. Type of Report and Period Covered

Final Report

14. Sponsoring Agency Code

15. Supplementary Notes

The primary purpose of this research was to develop a systematic method for the submission and review of safety cases towards waiver approval for operations outside the auspices of Title 14 of the Code of Federal Regulations part 107. The FAA identified many use case/safety case waiver applications were submitted with insufficient data and/or non-standard risk assessment practices to justify an equivalent level of safety towards operational approval. Challenges of non-standard submissions and practices has strained the FAA review process, further necessitating a method for a consistent approach to make informed decisions regarding the issuance of waivers for small, unmanned aircraft system (sUAS) operations. This research generated a framework prototype to address the problem of consistency with waiver submissions and FAA review. The problem addressed applicants and FAA reviewers simultaneously. The starting point was the FAA certificate of authorization (COA) forms, and as such, results of the present efforts fit more smoothly into existing online portals, which is an advantage regarding their potential implementation. The product was validated using a tabletop test case exercise as a validation effort with key FAA stakeholders. This resulted in an assessment of the framework's applicability to BVLOS waiver submissions and generated valuable feedback from participants. Future work should explore the application of this framework in a web-based platform and assess its applicability and final integration into the process.

17. Key Words

18. Distribution Statement

This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classification. (of this report)	20. Security Classification. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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TABLE OF ACRONYMS

Acronym	Meaning
ADS-B	Automatic Dependent Surveillance-Broadcast
ASSURE	Alliance for System Safety of UAS through Research Excellence
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
AUVSI	Association for Unmanned Vehicle Systems International
BVLOS	Beyond Visual Line of Sight
CFR	Code of Federal Regulations
COA	Certification of Authorization
CONOPs	Concept of Operations
DAA	Detect and Avoid
FAA	Federal Aviation Administration
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LOB	Lines of Business
NAS	National Airspace System
ORAP	Operational Risk Assessment Prototype
ORM	Operational Risk Management
RFI	Request for Information
RPIC	Remote Pilot in Command
SME	Subject Matter Expert
SORA	Specific Operations Risks Assessment
SRA	Safety Risk Assessment
SRM	Safety Risk Management
sUAS	small Unmanned Aircraft System
TIM	Technical Interchange Meeting
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
VLOS	Visual Line of Sight
VBA	Visual Basic for Applications
VO	Visual Observer

EXECUTIVE SUMMARY

With the advent of requests for complex Unmanned Aircraft Systems (UAS) operations in the National Airspace System (NAS), the Federal Aviation Administration (FAA) sought solutions for a more standardized, scalable approach to the waiver submission and review process for complex operations outside the auspices of Title 14 Code of Federal Regulations (CFR) Part 107. This need became evident as an increasing number of applications were receiving lengthy Requests for Information (RFIs) or outright rejection. The FAA identified many waiver applications were submitted with insufficient data and/or non-standard risk assessment practices to support and justify an equivalent level of safety towards operational approval. Challenges of non-standard submissions and practices have strained the FAA review process, further necessitating a method for a consistent approach to make informed decisions regarding the issuance of waivers for small, Unmanned Aircraft System (sUAS) operations. This is especially true for complex use cases such as Beyond Visual Line of Sight (BVLOS) operations, which were the primary emphasis of this research. BVLOS flight operations usually require more complex safety cases, requiring detailed information about the system, environment, hazards, risks, and mitigations. To address these challenges, the Alliance for System Safety of UAS through Research Excellence (ASSURE) A25 research team explored the development of a framework for industry stakeholders to submit standardized waivers requests to the FAA. This framework is intended to offer a means for collecting more consistent data for sUAS waiver applications, offering new toolsets for submitting and reviewing Part 107 waiver applications.

The following tasks were executed within the scope of this research:

1. Literature review and framework development
2. Low altitude risk assessment roadmap
3. Validation case studies
4. Reporting

These tasks helped the research team to identify minimum requirements for a risk-based waiver review framework and how this product could be seamlessly incorporated into existing FAA practices. In addition, the research team explored the applicability of industry standards for assessing risk and how these standards might aid applicants in obtaining a better understanding of common risk assessment practices. As a final component to this research, the team generated a low altitude risk assessment roadmap in response to industry concerns regarding pathways towards integrated, low altitude flight operations.

An output of this research was a prototype framework to address the problem of consistency with waiver submission and review guidelines. The output addressed applicants and FAA reviewers simultaneously. The starting point was the FAA Certificate of Authorization (COA) forms, and as such, results of the present efforts fit more smoothly into existing online portals, which is an advantage regarding their potential implementation. The result was tested over a test case for validation purposes, and it went through a tabletop exercise with key FAA stakeholders. This culminated in an assessment of the framework’s applicability to BVLOS waiver submissions and generated valuable feedback from participants. Future work should explore the application of this framework in a web-based platform and assess its applicability and final integration into the process.

1 Introduction

The performing team explored requirements and methodologies for developing a risk-based framework towards Part 107 (Small Unmanned Aircraft Systems, 2016) waiver review and issuance. As part of this effort, the research team explored key aspects of the 14 CFR Part 107 waiver process focusing on complex BVLOS flight operations. This final report highlights the key research questions, highlights key findings of the literature review, and provides insight into the development of a risk-based framework for waiver review and issuance. This report also captures and offers insight into lessons learned from the development of a roadmap for low-altitude risk assessment. Finally, this report consolidates conclusions in terms of key findings and recommends future work based on the findings associated with this research.

2 Research Questions

To address issues relating to the submission and review of 14 CFR Part 107 waivers, particularly for BVLOS flights, the research team focused efforts on answering the following research questions:

1. Can existing industry standards from the American Society for Testing and Materials (ASTM) International and the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) Specific Operations Risk Assessment (SORA) inform a framework for applicants to articulate the risk components necessary for the FAA to review Part 107 waivers?

2. What are the minimum requirements for a risk-based framework to review Part 107 waivers?

3. How does a risk-based framework to review Part 107 waivers fit into the current waiver review process?

These research questions address challenges associated with (1) how industry standards may be leveraged to address current challenges facing the FAA when reviewing waivers, (2) minimum requirements for waiver review, and (3) how a standardized approach may fit into existing FAA processes.

3 Literature Review

The project began with a thorough literature review to explore multiple facets of 14 CFR Part 107, the current waiver process, risk assessment practices, and industry standards. Its purpose was to provide tools and insight to the FAA to:

1. Assist in the development of a more standardized reviewing process for Part 107 (Small Unmanned Aircraft Systems, 2016) waivers, and

2. Address challenges faced by FAA reviewers when evaluating Part 107 waivers where applicants were using non-standard risk assessment methodologies.

This was accomplished by:

1. Suggesting modifications to FAA orders 8040.4B, "Safety Risk Management Policy" (Federal Aviation Administration, 2017) and 8040.6, "Unmanned Aircraft Systems Safety Risk Management Policy" (Federal Aviation Administration, 2019),

2. Developing a framework to modify the existing Part 107 waiver process, and enabling harmonization with alternative risk assessment methodologies (e.g., ASTM and JARUS SORA), and

3. Validating the proposed framework through test cases.

The literature review aided the research team in defining the project's scope and scale and served as the foundation for follow-on research tasks. For the sake of brevity, this report will capture key points of the most critical sections of the literature review, provide an overview of the literature review methodology, and highlight the resulting conclusions and recommendations. Readers should address the original sources for expanded information.

a. Expanded UAS Operations in the NAS

Title 14 CFR Part 107 serves as a starting point for industry stakeholders to pursue more complex expanded and non-segregated operations in the National Airspace System (NAS). At present, operations conducted outside the auspices of 14 CFR Part 107 must be submitted to and reviewed by the FAA through a case-by-case safety waiver application submission process. However, industry stakeholders often do not understand the extensive nature and content of waiver submission materials needed by the FAA to assess and approve advanced operations. The need for the applicant to provide robust justification to validate an equivalent level of safety for the approval for the UAS to perform expanded operations is often not understood, creating a gap between the waiver applicant and the FAA. This gap often results in rejection of applications to perform advanced operations, or an RFI exchange between the FAA and the waiver applicant, causing extensive delays to the FAA application, submission, and review process. This section will further highlight potential limitations regarding the aforementioned.

b. Part 107 Limitations

While Part 107 enables routine access to Class G airspace at altitudes below 400 feet above ground level while maintaining Visual Line of Sight (VLOS), it also imposes several limitations that UAS operators may eventually need to address with the FAA in order to allow for expanded operations. These limitations were already recognized when 14 CFR Part 107 was drafted, as the FAA Modernization and Reform Act of 2012 indicates. This act states,

> "Because UAS constitute a quickly changing technology, a key provision of this rule is a waiver mechanism to allow individual operations to deviate from many of the operational restrictions of this rule if the Administrator finds that the proposed operation can safely be conducted under the terms of a certificate of waiver" (FAA Modernization and Reform Act, 2012).

Thus, 14 CFR Part 107 (Small Unmanned Aircraft Systems, 2021) contains provisions for waiving individual regulatory requirements specified within section §107.205:

> (a) Section §107.25—Operation from a moving vehicle or aircraft. However, no waiver of this provision will be issued to allow the carriage of property of another by aircraft for compensation or hire.
> (b) Section §107.29—Daylight operation.
> (c) Section §107.31—Visual line of sight aircraft operation. However, no waiver of this provision will be issued to allow the carriage of property of another by aircraft for compensation or hire.
> (d) Section §107.33—Visual observer.
> (e) Section §107.35—Operation of multiple small unmanned aircraft systems.
> (f) Section §107.37(a)—Yielding the right of way.
> (g) Section §107.39—Operation over people.
> (h) Section §107.41—Operation in certain airspace.
> (i) Section §107.51—Operating limitations for small unmanned aircraft.

At the beginning of this research project, the team identified night operations (§107.29), operations over people (§107.39), beyond visual line of sight (§107.31), and visual observer (§107.33) as the sections of Part 107 that have historically received the most waiver requests from operators as outlined in Figure 2. However, Amendment 8 to Part 107 was published in January 2021 and provides criteria that now allow for permissible night operations and operations over people. Due to the publication of this amendment, the number of waiver requests for night operations and operations over people was expected to decrease, and so in response the primary focus of the research shifted to an emphasis on BVLOS and VO waivers. These waiver requests also often include requests to perform complex BVLOS operations with electronic visual observers, using technology such as automatic dependent surveillance broadcast (ADS-B (in)), remote ID, or detect and avoid (DAA) sensors, which can make obtaining the waiver more challenging, which provided a second impetus for focusing on BVLOS and VO operations.

It should be noted that the 14 CFR Part 107 waiver process does not include provisions for waiving aircraft weight, neither does it provide an avenue for the carriage of property for compensation or hire. Presently, the regulations allow for property carriage only within state boundaries and if the total weight, including payload and cargo, is less than 55 pounds (with some exceptions in Hawaii and Washington D.C.). However, these restrains prevents many businesses to expand, and it is possible that authorizing the use of a waiver in such operations would greatly benefit the UAS community.

c. Part 107 Waiver Process

Some waiver applicants have experienced difficulty with the waiver application process. Each request is unique, which raises difficulties when trying to standardize the review. And yet, a common, public process would be of much help to applicants, who sometimes find themselves lost in administrative procedures. The waiver process involves a multi-step approach, which begins when the applicant submits a request through FAADroneZone. Once it is assigned to an analyst, a receipt of the waiver request is produced. The analyst evaluates the request, and as a result, he/she makes a decision to approve or deny an applicant's request. The process is shown in Figure 1, which is an excerpt from the FAA's "Where's My Waiver" webinar (Morris, 2018). This webinar was designed to provide potential and actual applicants with an overview of the Part 107 waiver process.

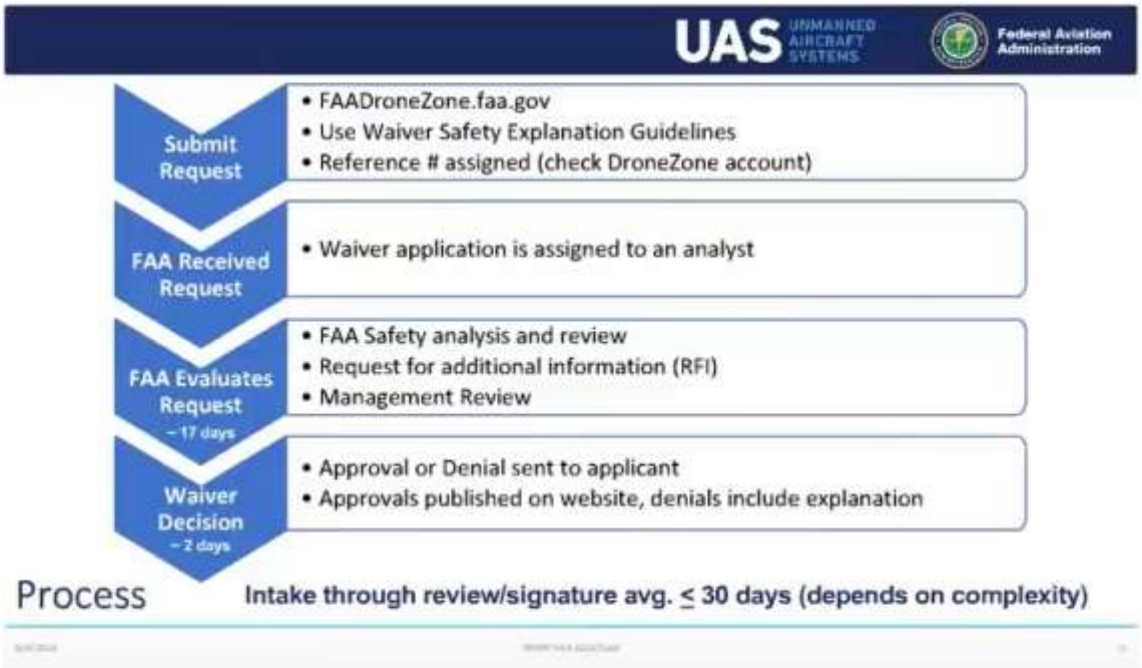

Figure 1. The waiver review process as shown in the FAA's 'Where's My Waiver' webinar.

While the figure indicates that the entire waiver process, from submission to approval, should not exceed 30 days, this is not always the case. The time for approval strongly depends on the operation's complexity and the nature of the relief sought by an applicant.

Information captured in waiver applications is found within 84 FR §32512 (Small Unmanned Aircraft Systems [sUAS] Waivers and Authorizations, 2019). Most of these items are relatively simple, requiring little more than basic information from the applicant. However, putting all the required information together in a justifiable safety case can be challenging. While there is guidance available to applicants in the form of safety explanation guidelines, suggestions for safety arguments, and other useful information available on the FAA's Part 107 waiver website, obtaining waivers for complex operations, particularly BVLOS, is still challenging.

d. UAS Trend Analysis for Part 107 Waivers

The FAA maintains an open record of all Part 107 waivers that have been approved, posting details that may be shared publicly on their Part 107 Waivers Issued website (Federal Aviation Administration, 2020). While this website does not contain any proprietary information or specific details regarding how/why these waivers were approved, it provides a useful "snapshot" of the types of operations that have gone through the process. To further analyze available data regarding waiver approvals, the Association for Unmanned Vehicle Systems International (AUVSI) published a report titled *New Part 107 Waiver Report – Analysis of Advanced Operations Granted by the FAA: Waivers over time, entities granted waivers, and the path ahead* (AUVSI, 2020). This report was consulted alongside the FAA's Waiver Trend Analysis to better understand the number and types of operations that the FAA typically approved. As shown in Figure 2, most approvals were requests for night operations, with a small number of waivers granted for BVLOS flight operations, and even fewer for waiving visual observer requirements.

Figure 2. Waivers granted for type of operations (AUVSI, 2020).

e. Review of Title 14 CFR Part 107 and the existing waiver process

Some of the more commonly recognized guidelines to develop a Safety Risk Management (SRM) process were analyzed in detail: MIL-STD-882E (Department of Defense, 2012), JARUS SORA (Joint Authorities for Rulemaking of Unmanned Systems, 2019 January 30), and AC 107-2 (Federal Aviation Administration, 2016). This analysis compared FAA orders 8040.4B (Federal Aviation Administration, 2017) with 8040.6 (Federal Aviation Administration, 2019).

In addition to the aforementioned common SRM guidelines, the research team analyzed industry consensus standards regarding SRM. As a result of this work, the research team identified industry best practices and standards in addition to those already contained in FAA orders 8040.4B and 8040.6 were highlighted.

f. Conclusions and Recommendations

The literature review identified several gaps in need of being addressed as a risk-based framework for evaluating Part 107 waiver evolved using FAA Orders 8040.4B (Federal Aviation Administration, 2017) and 8040.6 (Federal Aviation Administration, 2017). The following aspects were identified as potential improvements to the current process:

- A need to standardize definitions for common Safety Risk Assessment (SRA) terminology and concepts.
- A need to standardize SRAs developed by entities seeking a Part 107 waiver. This standardization process should meet FAA order 8040.4B/8040.6 and ensure a more uniform approach to risk assessment and acceptance.
- A need to standardize a single risk matrix chart that could be used across various FAA Lines of Business (LOBs), or alternatively leave each FAA LOBs to develop their own specific risk matrix chart. In any case, the risk matrix should be made accessible to all stakeholders. It is the group's belief that a single risk matrix chart that fixes safety terms while matching the specific UAS operational environment is a more robust solution since it helps bridge various FAA LOBs.
- A need to include compliance-based methodologies, standards, and regulations outside of Part 107 in the waiver request process where appropriate, as additional regulations and policies are developed.
- A need to include data collected through the safety assurance process as defined in FAA Order 800.369C, Safety Management Systems, effective June 24, 2020. Also, the need to include FAA-recognized research data in the risk acceptance framework. When used by applicants, these data sets should be part of the decision process to determine the level of risk and inform on the existing and potential risks of their respective operations.

4 Framework Development

Following the literature review, the research team began developing a risk-based framework for waiver submission and review. The goal was to develop a mechanism to improve the FAA waiver review process while simultaneously enabling the applicant to apply for a waiver request with a better understanding of what information is needed.

The starting point for this framework was existing FAA insight as to why some waiver requests are rejected (Federal Aviation Administration, 2021, March 31). This data covered three specific cases: BVLOS operations, operations over people, and night operations. The findings are summarized below:

- *BVLOS waivers applications*. More information is needed on C2 links, DAA methods, weather tracking, and training requirements.
- *Operations over people*. More information is needed on ground collision severity, laceration injuries, operation description, and remote pilot experience.
- *Night operations*. More information is needed on visual conspicuity, see-and-avoid methods, sUAS's location and movement information, and the participant's knowledge requirement.

a. Approach

The development of a waiver review process based on risk was a challenging task, as the approach needed to reflect the need for applicants to have a clear understanding of the information required to develop a safety case while providing consistent mechanisms for FAA to undertake the review. To address these concerns, the research team approached the problem from two directions simultaneously:

1. The Applicant – According to the FAA's Waiver Trend Analysis (Federal Aviation Administration, 2021, March 31), applicants were often either a) unaware of what types of information should be included in a 14 CFR Part 107 waiver submission, and/or b) were often unfamiliar with accepted aviation practices for presenting information and Safety Risk Management/Operational Risk Management (SRM/ORM). The implication is that applicants need more robust guidance on the information that the FAA needs to make a decision regarding a safety case, and the FAA needs a mechanism for ensuring consistency when reviewing information from applicants.

2. FAA Part 107 waiver reviewers – Conversely, FAA reviewers experience challenges when attempting to evaluate a request submitted by applicants that do not have proper guidance. The group considers that, for the sake of transparency, FAA and applicants' guidelines should be the same.

With this vision in mind, the research team leveraged the literature review, the collective experience of the team's members, and the insight from FAA Subject Matter Experts (SMEs) to derive the risk-based framework.

Initial concepts for a risk-based framework to be used during a waiver submission and approval process were based upon the application and/or adaptation of the accepted FAA SRM processes outlined within FAA Order 8040.4B (Federal Aviation Administration, 2017, May 2). This approach was intended to address one of the key conclusions that resulted from the FAA's Waiver Trend Analysis (Federal Aviation Administration, 2021, March 31) – the lack of sufficient safety case information provided by waiver applicants due to a.) an unawareness of information requirements for waiver submissions, and/or b.) unfamiliarity with aviation practices for presenting information on SRM/ORM.

In addition to considerations regarding the incorporation of conventional SRM processes, the research team received insight from FAA stakeholders regarding the concept of "scalable compliance." The concept of scalable compliance seeks to establish risk-based standards for operational approval that use a "build-up" approach and layers of additional mitigations needed to offset increasing levels of risk. In short, the scalable compliance process is predicated on the gradual buildup of test artifacts and/or data points over time. These test artifacts/data points, when aggregated over time, can lead to increased latitude in granting operational approvals. Thus, it is increasingly important that the FAA develop the means to consolidate and re-use data from approved 14 CFR Part 107 waivers. This aggregated data may serve as the basis for acceptable means of compliance in the future as regulations are amended to allow for expanded operations and may also highlight new/novel hazard mitigation techniques. However, it should be noted that some of the information contained within waiver requests may be proprietary to the applicant and is restricted from sharing. This creates roadblocks when it comes to comparing data from separate waiver requests. The existence of proprietary data within waiver submissions may also prevent sharing waiver applications publicly.

To address considerations for scalable compliance review and the need for consistent means of articulating key information for a Part 107 waiver safety case, the research team explored the adaptation of multiple risk-based constructs into a waiver application/review framework. This process began with an exploration of common SRM processes. The task involved cross-referencing concepts from FAA Order 8040.6 (Federal Aviation Administration, 2019 October 4) and the JARUS SORA (Joint Authorities for Rulemaking of Unmanned Systems, 2019 January 30) to achieve a balance between qualitative and quantitative approaches to SRM and ORM practices. A gap analysis was thus performed comparing 8040.6 order (Federal Aviation Administration, 2019 October 4) steps with equivalent steps in SORA. Results were classified based on the responsible party, i.e., the FAA or the applicant, and used to enhance the 8040.6 process.

As part of this task, the research team also consulted a proprietary internal toolset used by the FAA to review a waiver submission: the Operational Risk Assessment Prototype (ORAP). The use of this interface as a helping tool for the applicant was considered efficient. Thus, a similar framework was used in this case –adapted to different inputs and not including calculations in the background.

Following this review, the team concluded that the common thread throughout all common SRM processes was the necessity for consistent, credible data sets. This conclusion ultimately drove data sets that make up the framework developed for this task. Figure 3 highlights a high-level conceptual approach that the team used to derive the framework – based upon a thorough review of foundational SRM and ORM practices and the identification of gaps. Figure 3 highlights source literature – e.g., FAA Orders 8040.4B/6, JARUS SORA, ASTM F3178-16, and the FAA's proprietary ORAP toolset, which ultimately drove common data sets and considerations for the risk-based framework for waiver submission and review.

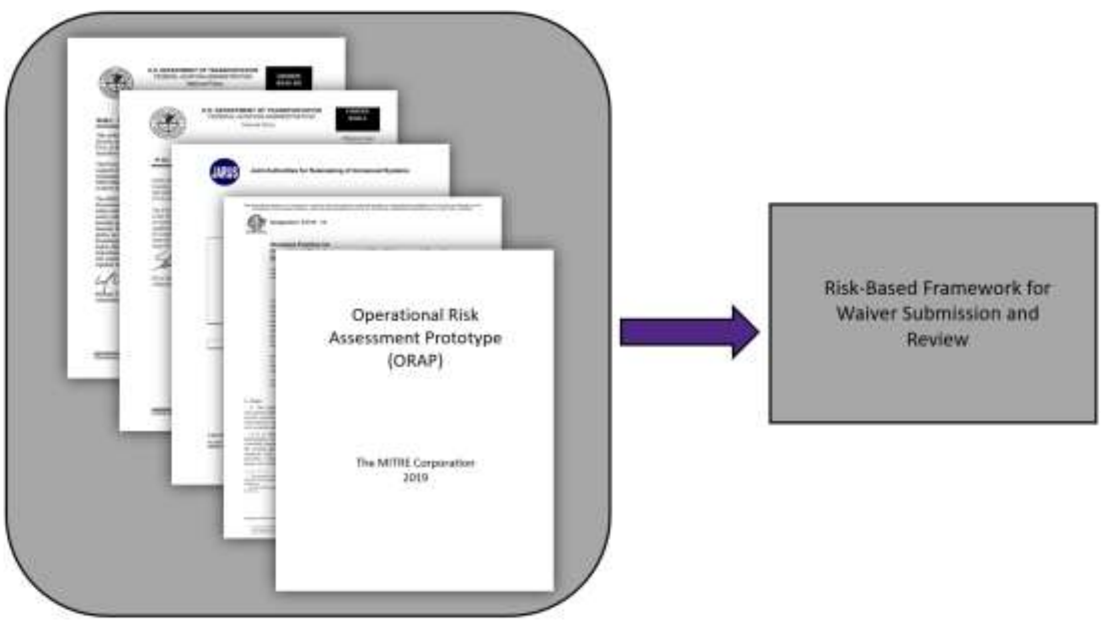

Figure 3. Risk-Based Framework for Waiver Submission and Review Source Material.

The conclusion that consistent, accurate data drives SRM, and by extension, scalable compliance, led the team to focus on the development of a waiver submission and review framework that promotes the collection of key safety case data. To ensure this, successful COA applications were reviewed, and lessons learned there were included in the SORA/8040.6 comparison analysis indicated above.

b. Overview of Framework

The waiver application framework consisted of a compilation of user-defined forms created using the Visual Basic for Applications (VBA) feature in MS Excel. The forms were representative of the proposed COA system that can help provide waivers for civil UAS users. Excel VBA provides an opportunity to customize and manipulate graphical-user-interface features such as toolbars, dialog boxes, and forms that are normally not available with default MS Office applications. The VBA UserForm feature can help collect information from applicants. The top-level hierarchy of this framework can be classified into public and private. Since the public COA system is already in place to provide waivers for public users, the first form in this framework helps to distinguish if the applicant is a public user or a private user. If the applicant identifies as a public user, the framework will redirect the user to the public COA system housed in the FAA's website. If the applicant identifies as a private (civil) user, the user would have to navigate through the various forms in this application framework to provide information that can lead to the issuance of a waiver for civil purposes.

The framework was divided into the following sections/forms. What follows are brief summaries of the individual sections:

- *Type of Applicant Information*: This section of the framework distinguishes between private and public UAS users.
- *Applicant Information*: This form captured the applicant's primary information, including their organization/institution affiliation.
- *Declarations*: This segment consists of declarations to ascertain the applicability of the framework and assert the applicant's conformance to applicable regulatory requirements.
- *Point of Contact Information Form*: This form helps to collect point of contact information within the organization that the FAA can use for the sake of communication during the waiver review, follow-on, and approval process.
- *Operational Description (Part 1, 2, and 3)*: This section consists of three parts which capture key details of the proposed operation, including operational strategy, airspace classification, operational area, and length and type of operation. The overarching hazards of the operation are generally deduced from the description provided in this section.
- *UAS Platform (Part 1 and 2):* This part of the framework helps describe key UAS performance indicator information that can be usually found on the UAS manual.
- *Flight Aircrew Qualifications:* This section captures critical information regarding the flight crew, including their experience, training, and certification levels
- *Flight Operational Area (Part 1 and 2):* This segment is comprised of important operational area information such as latitude and longitude, the population in the operational area, and operational speed and altitude of the UAS.

- *Visual Surveillance*. This section contains key VO-related information such as means of communication with the Remote Pilot in Command (RPIC), credentials, training, and certification of VO.
- *Safety Management*: This form incorporates details about the safety liaison personnel in that organization, including their contact information, previous experience, and the organization's safety management system.
- *Technical Issue with UAS (Part 1, 2, 3, and 4)*: These parts enable the collection of important information regarding UAS technical risks and whether those risks contribute towards a hazard.
- *Human Factors (Part 1, 2, and 3):* This heading consists of three forms that capture the impact of human error in the overall operational safety and whether those errors cause an operational hazard.
- *UAS Operations (Part 1, 2, and 3):* A three-part form under this section captures various operational information and procedures that may or may not become a hazard for the operation that needs to be identified for the FAA.

Figure 4 shows an example of one of the data forms that make up the Framework. Each data entry form has fields that are unique to its given category. Additional examples of these forms may be found within the Framework itself (Appendix A).

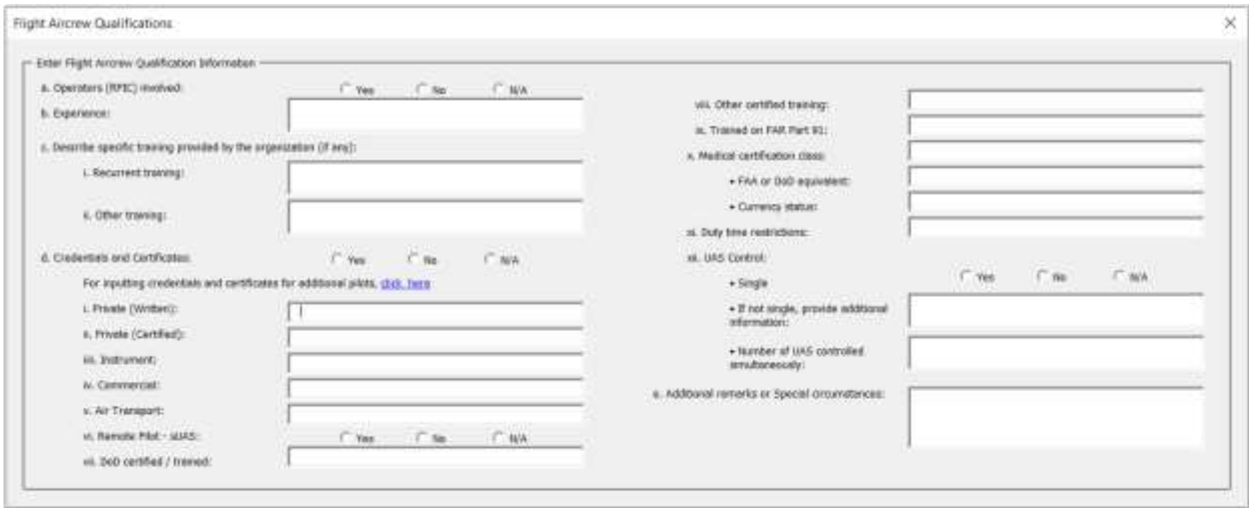

Figure 4. Example Data Entry Form - Flight Aircraft Qualifications.

c. Initial Recommendations

The research team derived an initial recommendation from the prototype framework developed as part of Task 1-2. This recommendation took the form of a high-level guidance document that recommends amended language to AC 107-2A. This guidance document can be found in Appendix A.

The guidance document generated for this task has two primary goals. First, it is intended to recommend language revisions to AC 107-2A, providing additional information for applicants who may wish to utilize the prototype framework. Second, it serves as a starting point for FAA reviewers to assess the information contained within each segment of the prototype waiver submission/review framework. While the guidance is fundamentally at a high level, it serves as a starting point for outlining a methodology to enable Part 107 waiver applicants to provide more relevant data to build their supporting safety case. Likewise, it provides a starting point to draft further FAA guidance that could establish a standardized method for reviewing the information contained within each segment of the framework. The result is a steppingstone towards a more streamlined, consistent system for waiver submission and review.

5 Low-Altitude Risk Assessment Roadmap

UAS operators can spend significant effort and resources to obtain the data needed to prove the safety of their operations at a specific location. Because the approval of a UAS operator's operation is location-specific, the operator must repeat the approval process for each new location using data appropriate for that location. As a result, industry stakeholders asked the FAA to develop a quantitative method for assessing the risk of a low-altitude operation anywhere in the country. They specifically asked for a study that would include factors such as traffic density, weather, population density, terrain, land use and zoning, building heights, and other local factors to determine the probabilistic level of risk at any location in the country.

The FAA tasked the research team with this endeavor. The research team used input from subject matter experts, ongoing ASSURE research, and knowledge of risk assessment practices and methodologies to develop a Low-Altitude Risk Assessment Roadmap (Appendix B) for identifying risks associated with low-altitude UAS operations and potential data sources for characterizing those risks. The Roadmap was the research team’s effort to identify the data categories required to characterize low-altitude airspace environments and identify the associated data gaps. The team expected the roadmap to inform follow-on research to expand these data categories into populated sets of information that would point towards (1) standards and practices for low-altitude risk assessment and (2) policy regarding low-altitude UAS operations.

The FAA sponsors provided feedback on the Roadmap that suggested a need for industry consensus standards to help accelerate technological advancements and supplement gaps that currently exist within the regulatory framework for unmanned systems. The push towards standards development raises the value of the ASSURE research described in the Roadmap document. ASSURE researchers participate in industry consensus standards groups and bring the lessons learned through their ASSURE research to the standard development efforts. This approach enables a translation of research outcomes to industry and enables a means to validate findings. The Roadmap document highlights some key areas where ASSURE researchers have made significant contributions to the body of knowledge, helping to steer industry focus and inform solutions to various challenges facing the UAS industry as a whole.

6 Validation Case Studies

The framework contains what the research team determined to be a thorough, but not overwhelming, set of information for a UAS operator to submit to allow for a sufficient review of a complex safety case by FAA personnel. The research team needed to conduct an evaluation of the framework to determine if the information requested in the framework aligned with the information provided by operators in previously approved, complex 14 CFR Part 107 waivers. Due to the release of the rule for operations over people and the release of new rules for night operations that eliminate the need for night waivers, the sponsor directed the research team to focus on waivers associated with both extended visual line of sight and true BVLOS. For the purposes of this research, the emphasis was on waivers for 14 CFR 107.31 (Visual line of sight aircraft operation) and 14 CFR 107.33(b) and (c)(2) (Visual observer). The decision to focus on BVLOS was reached through a collective agreement between the research team and the sponsor through technical interchange meetings (TIMs) and a stakeholder focus group that drove the project's overall scope.

a. Approach

The University of Alaska Fairbanks (UAF) provided two approved Part 107 waivers for BVLOS operations, and the information provided to the FAA when they submitted the waivers for conducting the validation case studies. The first waiver, 107W-2018-14511, covers extended visual line of sight operations over the Trans-Alaska Pipeline northeast of Fairbanks, Alaska. The second waiver, 107W-2020-04368, covers true BVLOS operations over the Trans-Alaska Pipeline northeast of Fairbanks, Alaska.

The information from the waiver submission packages was mapped to the framework and the team identified the differences between what was in the packages and what was requested in the framework. One challenge of the mapping exercise was that DroneZone's waiver submission portal limits the number and size of the documents supporting a waiver application. This led UAF to limit the amount of information provided about potential sources of human error and other information not deemed as important to the successful evaluation of the waiver application.

The research team conducted a tabletop validation exercise with FAA subject matter experts on November 3, 2021. The exercise focused on the more complex waiver, 107W-2020-04368. During the exercise, the team stepped through each page of the framework, highlighted what was included or not included in the 107W-2020-04368 waiver submission package, and identified a few limitations of the framework that would have complicated the waiver submission process. The excel spreadsheet the team used to conduct the exercise is included as a series of worksheet snapshots in Appendix C. It includes examples of the information the UAF team uploaded in their waiver submission, how the UAF team would have answered the questions, and research team comments identifying differences between the framework, and what the UAF team uploaded.

b. Outcomes

The primary conclusion from the tabletop validation exercise is that the framework captures almost all of the key pieces of information the subject matter experts want included in a safety case and that the UAF team had provided in their successful waiver requests. The key area of difference between the framework and the submitted UAF safety case was the human factors section of the framework. The UAF team did not include most of the information requested in that section because they considered the information requested in that section as covered by the normal operational policies and procedures of professional UAS operators and not something that actually needed to be included in the waiver request. A less professional operator will benefit from considering the factors identified in the human factors section.

The subject matter experts and research team identified a few areas for improvement. They include:

- Adding an executive summary with a high-level description of the request, such as “BVLOS with Detect and Avoid for linear infrastructure inspection.”
- Adding a place to input previous or similar waivers with only slight differences that will be highlighted at the front of the waiver application and that will have almost identical waiver packages.
- Including a supporting documentation page that will include one-sentence descriptions of each uploaded supporting document.
- Allowing the input of operational area instead of just a point and radius.
- Increasing the information about the UAS by adding a narrative about the system. For example, if an aircraft splits into two aircraft during flight, that fact would be included in the narrative.
- Including a way to specify that there is an electronic observer, a crewmember who is tasked with monitoring the Detect and Avoid systems used to ensure airspace awareness.

7 Conclusions

This effort explored questions relating to the standardization of and minimum requirements for a risk-based means for submitting and reviewing waivers for 14 CFR Part 107, emphasizing waivers for BVLOS flights. For this project, the research team conducted a thorough literature review and used this to construct a framework for Part 107 waiver submission and review. The research team also generated a roadmap for low-altitude risk assessment based upon queries from industry. The combined effort of these tasks offered the following answers to the project’s key research questions.

- *Can existing industry standards (ASTM, JARUS SORA) inform a framework for applicants to articulate the risk components necessary for the FAA to consider Part 107 waivers?*

Ultimately, it was found that existing industry standards can play a role in informing a framework, but these play more of a role in defining key information that applicants should provide to the FAA when submitting a waiver. This is particularly true regarding standards concerning ORA and SRM. Existing industry standards, such as ASTM F3178-16, can provide applicants with useful tools for assessing operational risk. This is especially true, as it complements existing FAA guidance and practices.

The Low-Altitude Risk Assessment Roadmap demonstrated that the information required to identify risks associated with low-altitude operations across the country is available from a variety of sources. However, the FAA sponsors clarified that the best way to an operational approval is not through more ground and air risk analyses; it is through standards development. The summary of the ASSURE research efforts included in the Low-Altitude Risk Assessment Roadmap shows that ASSURE researchers are testing and validating the technologies and processes required to inform industry standards. As the UAS industry develops new standards, they will identify knowledge gaps that will lead to new FAA requirements for the ASSURE researchers.

- *What are the minimum requirements for a framework for a risk-based standard for reviewing Part 107 waivers?*

Minimum requirements for a framework for risk-based standards for reviewing Part 107 waivers emphasize the collection and presentation of data. As noted within the literature review, deficiencies in Part 107 waiver applications primarily consisted of instances where applicants provided insufficient or otherwise poor information and/or data to support a given safety case. As such, a framework for waiver submission, and ultimately FAA review, must do two things:

1. It must guide applicants, particularly those with little aviation background, to identify and convey key information regarding their system, proposed operation, and their overall safety case in a manner that the FAA needs to support waiver evaluation.
2. It must present information in an orderly, consistent manner that enables the FAA's waiver review personnel to make consistent, predictable decisions regarding a given safety case.

Bearing these things in mind, the research team developed a framework that was derived from an existing FAA process – public COA submission forms, while emphasizing the unique differences in regulation, policy, and requirements inherent to Part 107 waiver applications. This approach allows for the collection of critical data that drives risk assessments and promotes a complete understanding of a given waiver submission. Furthermore, this approach follows a general format that is already in use by the FAA, mitigating the need for reviewers to become familiar with an entirely new process. An example of this framework can be found in Appendix A.

- *How does a risk-based standard for reviewing Part 107 waivers fit into the current waiver review process?*

A risk-based standard for reviewing Part 107 waivers should be intrinsic to the waiver review process. As such, the process for the submission and review of Part 107 waivers should incorporate elements that enable an accurate portrayal of an applicant's safety case. This, in turn, allows the FAA to make determinations accurately and consistently on whether to grant or deny a waiver request. The research team approached this by using a standardized template for the submission of key information such that a) the applicant can clearly understand what information is needed for a safety case, and b) FAA reviewers have a clear understanding of what the applicant intends to convey. In short, the entire process of submitting and reviewing Part 107 waivers should emphasize consistent data collection and presentation on both sides of the process – i.e., the applicant and the FAA review team.

8 Future Work

The primary outcome from ASSURE A25 was a prototype framework for enabling consistent data collection for use in building a safety case for 14 CFR Part 107 waivers. In addition, this prototype framework offers the potential to streamline the FAA's review process by means of establishing a generic template for building a safety case. However, as of the conclusion of this research, this framework requires additional development to create an implementable program. Future work should focus on the following aspects of this research, with an emphasis on paths to implementation and refinement of the framework to suit the needs of both the FAA and Part 107 waiver applicants:

1. Integration into a web-based client – The prototype framework generated as part of this task is intended for use as a data entry system. As such, integration into a web-based client could serve as a means for data entry, similar to the interface used for the FAA's COA application system.
2. Data Analytics – The structure of the prototype framework developed for this research lends itself to populating a database for relevant data categories associated with given unmanned systems, Concepts of Operations (CONOPs), and use cases.
3. Linkage to other ASSURE research – There are linkages between this research and other ASSURE projects – A24, particularly in the realm of database creation for use in cross-referencing data from waiver applications.

In addition to the three areas of future work identified, the risk-based framework developed as part of this research has the potential to fit into a larger system that promotes expedited, simplified waiver approvals. Beyond being a simple component to a web-based client, the risk-based framework could be incorporated into an online waiver system, such as that depicted in the conceptual diagram in Figure 5.

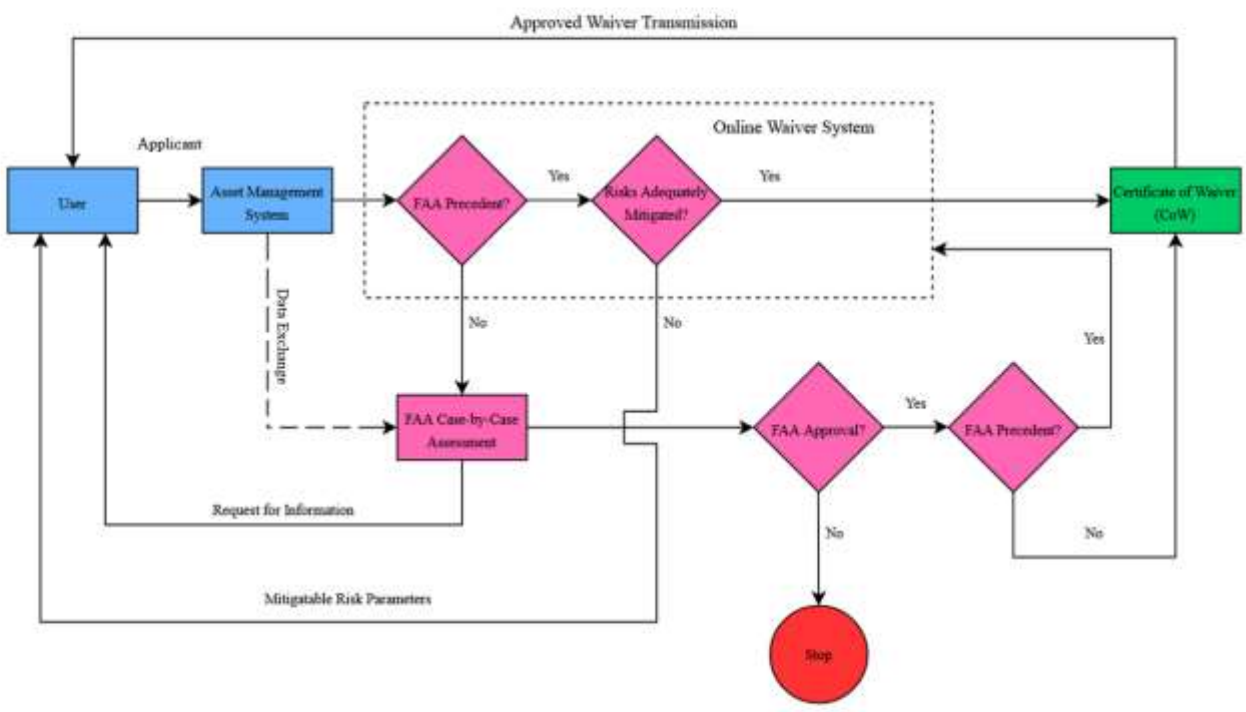

Figure 5. Conceptual Model for Precedent-Based Online Waiver System.

This system would take in user input in the form of a Part 107 waiver submission via an asset management system and enable precedent-based outcomes for waiver submissions. Future work could explore the development of the system depicted in Figure 5, and explore the implications of building the risk-based framework into a waiver submission mechanism.

Finally, the University of North Dakota research team is pursuing an independent validation of the risk-based framework for waiver submission and approval through the submission of two BVLOS waivers. At the time of the drafting of this report, these waivers are still in process. Feedback on the results of the process is anticipated at a later date.

9 References

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Small Unmanned Aircraft Systems (sUAS) Waivers and Authorizations, 84 FR §32512 (2019).

APPENDIX A – TASK 1-2: ABBREVIATED GUIDANCE FOR PART 107 WAIVER SUBMISSION/REVIEW FRAMEWORK[1]

[1] The information provided in Appendix A references the White Paper for ASSURE A25 – Develop Risk-Based Training and Standards for Waiver Review and Issuance: Task 1-2 Abbreviated Guidance that was submitted on August 13th, 2021. The authors of the report are Tom Haritos, Tim Bruner, Katie Silas, and Rajagopal Sugumar from Kansas State University Polytechnic, Catherine Cahill from the University of Alaska Fairbanks, and Paul Snyder and Marco Fernandez from the University of North Dakota.

Introduction

The purpose of this document is to provide a high-level overview of the proposed waiver application/review framework developed for ASSURE A25 Task 1-2: *Framework Development*. The framework developed for this task was based upon feedback gained from Stakeholder Focus Group meetings held on April 16th and 26th, 2021. These meetings provided valuable insight from the FAA sponsor and key stakeholders, providing the research team with much needed information to define clear objectives and deliverables for ASSURE A25 Task 1-2: *Framework Development*.

Overview

Task 1-2: *Framework Development* focused on creating a framework for consistent, effective submission and review of 14 CFR Part 107 waivers. This task is designed to be a natural extension of the literature review (Task 1-1) and incorporated lessons learned from stakeholder focus groups, the JARUS SORA, FAA Order 8040.6/4B, and an analysis of the FAA's ORAP template. This framework and subsequent guidance addresses challenges related to both (1) capturing information required to build a robust safety case for a 14 CFR Part 107 waiver application, and (2) reviewing waiver submissions in a manner that delivers reliable, consistent results. This task emphasizes waiver submissions for §107.31 – Visual Line of Sight Aircraft Operation, but the framework is designed to be applicable to most, if not all, Part 107 waiver submissions/use cases.

What follows is high-level guidance in the form of notional additions/revisions to FAA Advisory Circular (AC) 107-2A. The text that follows would precede 5.20 *Certificate of Waiver* and serve to highlight how the proposed framework would fit into the waiver submission paradigm. The goal is to provide the applicant with some baseline guidance as to what information may be required for a successful waiver submission while ensuring that FAA reviewers have sufficient data from the applicant to make an informed decision regarding a given waiver application. As such, waivers submitted via the proposed framework should be self-contained to the extent that the information they contain should be of sufficient detail to minimize the need for a RFI from the FAA following a submission and an initial review of an applicant's safety case. This guidance also incorporates an appendix that highlights a walkthrough of the framework for the sake of providing the reader with a visual representation of the framework itself.

Guidance

The following text represents excerpts from AC 107-2A with notional additions to address the draft framework developed as part of ASSURE A25 Task 1-2. The following material is taken directly from the most current version of AC 107-2A and modified to support findings of ASSURE A25 Task 1-2. The intent of this guidance is to inform a "drop-in" revision to the current Part 107 AC.

5.20 **Certificate of Waiver**. Part 107 includes the option to apply for a Certificate of Waiver (CoW). This CoW will allow a Small Unmanned Aircraft System (sUAS) operation to deviate from certain provisions of Part 107 if the Administrator finds that the proposed operation can be safely conducted under the terms of that CoW. A list of the waivable sections of Part 107 can be found in § 107.205 and are listed below:

• § 107.25, Operation from a moving vehicle or aircraft. However, no waiver of this provision will be issued to allow the carriage of property of another by aircraft for compensation or hire.
• § 107.29, Daylight operation.
• § 107.31, Visual line of sight aircraft operation. However, no waiver of this provision will be issued to allow the carriage of property of another by aircraft for compensation or hire.
• § 107.33, Visual observer.
• § 107.35, Operation of multiple small unmanned aircraft systems.
• § 107.37(a), Yielding the right of way.
• § 107.39, Operation over people.
• § 107.41, Operation in certain airspace.
• § 107.51, Operating limitations for small unmanned aircraft.

5.20.1 Applying for a CoW. To apply for a CoW under § 107.200, an applicant must go to www.faa.gov/uas/ and follow the instructions.

5.20.2 Application Process. The application must contain a complete description of the proposed operation and a justification, including supporting data and documentation (as necessary), that establishes that the proposed operation can safely be conducted under the terms of a CoW. Although not required by Part 107, the FAA encourages applicants to submit their application at least 90 days prior to the start of the proposed operation. The FAA will strive to complete review and adjudication of waivers within 90 days; however, the time required for the FAA to decide regarding waiver requests will vary based on the complexity of the request. The amount of data and analysis required as part of the application will be proportional to the specific relief that is requested. For example, a request to waive several sections of Part 107 for an operation that takes place in a congested metropolitan area with heavy air traffic will likely require significantly more data and analysis than a request to waive a single section for an operation that takes place in a sparsely populated area with minimal air traffic. If a CoW is granted, that certificate may include specific special provisions designed to ensure that the sUAS operation may be conducted as safely as one conducted under the provisions of Part 107. A listing of standard special provisions for Part 107 waivers will be available on the FAA's website at http://www.faa.gov/uas/.

5.21 **Supplemental Operational Information**. Appendix B, Supplemental Operational Information, contains expanded information regarding operational topics that should be considered prior to operations.

Additional websites providing further guidance:

1) General Information to Apply for a Waiver
https://www.faa.gov/uas/commercial_operators/part_107_waivers/media/Part-107-Waiver-Section-Specific-Evaluation-Information.pdf

2) Waiver application Instructions[2]
https://www.faa.gov/uas/commercial_operators/part_107_waivers/media/waiver_application_instructions.pdf
3) Waiver Explanation Guidelines for Part 107 Waiver Applications
https://www.faa.gov/uas/commercial_operators/part_107_waivers/waiver_safety_explanation_guidelines/
4) Operational Risks and Mitigations Questions
https://www.faa.gov/uas/commercial_operators/part_107_waivers/waiver_safety_explanation_guidelines/media/WSEG_operational_risks_mitigations.pdf
5) Sample Justifications for Safety Waivershttps://www.faa.gov/uas/resources/policy_library/section_352_responses/
6) Webinar to fill out Safety Waiver
https://www.youtube.com/watch?v=y5QMw3BYn10
7) Webinar on how to do a risk assessment for successful waiver application
https://www.youtube.com/watch?v=1BAVK3OZajA
8) Logging into FAADroneZone
https://faadronezone.faa.gov/#/

In addition to the above guidance, Appendix F provides detailed instructions for the use of a process framework for Part 107 waiver applications.

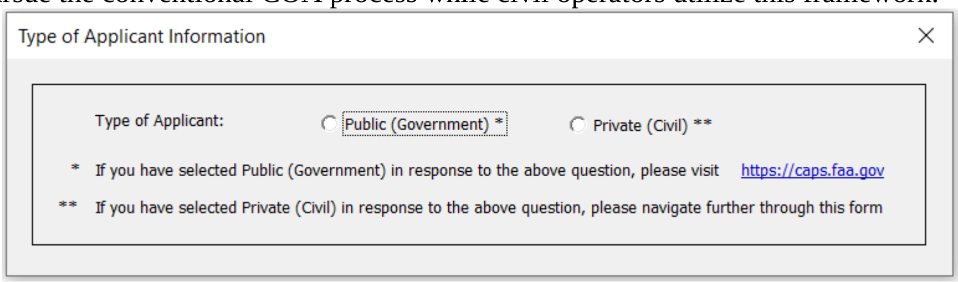
[2] This guidance has not yet been updated to reflect the most current version of 14 CFR Part 107 at the time this report was drafted. As of February 1, 2021, AC 107-2 was replaced by AC 107-2A.

Proposed Appendix – Supplement to AC 107-2A as Appendix F[3]

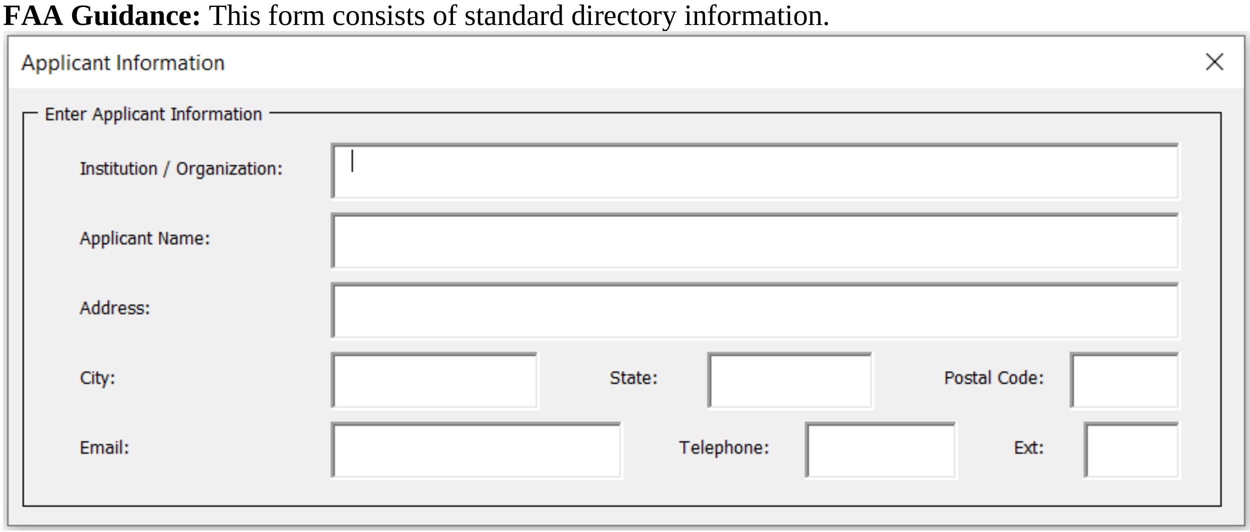
Introduction. The following appendix provides guidance for the use of the waiver application framework. This guidance provides an overview of each step in the process, offering an explanation for both applicants and FAA reviewers alike. Throughout this process, it is important to note that the terms, "sUAS" and "UAS" are used interchangeably.

Guidance for the use of Waiver Review and Submission Framework

Form: Type of Applicant Information
Applicant Guidance: Indicate the applicant type by selecting the appropriate radio button. If the applicant is requesting a waiver for 14 CFR Part 107 for commercial operations – e.g., operations for hire/compensation, use the "Private (Civil)" option. If the applicant is a local, state, federal, or tribal government entity, select the "Public (Government)" option, and proceed with the conventional Public Certificate of Authorization (COA) process.
FAA Guidance: This segment of the framework distinguishes between civil and public operators. Public operators pursue the conventional COA process while civil operators utilize this framework.



Form: Applicant Information
Applicant Guidance: This form consists of primary information that describes the applicant. It includes any affiliated institution or organization – e.g., business if applicable, name, address, and any pertinent identifying information.
FAA Guidance: This form consists of standard directory information.

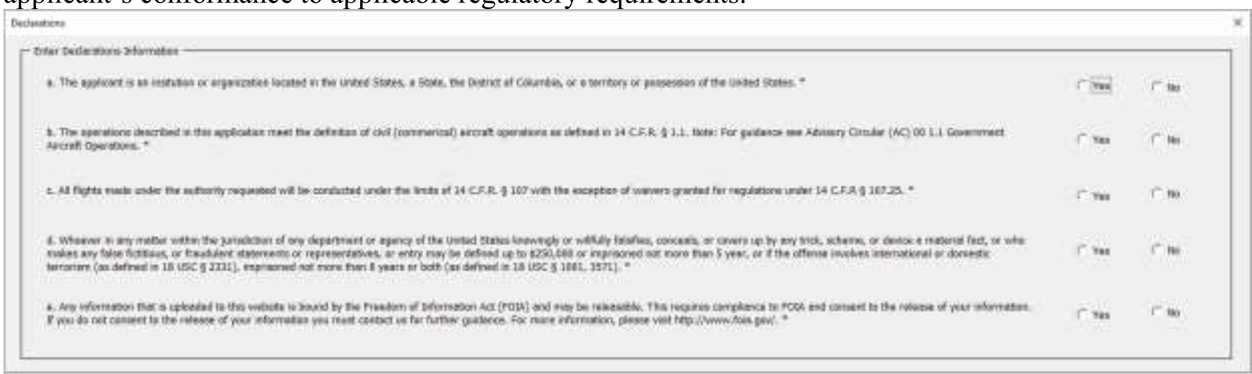


[3] The original title of the Appendix when submitted in the White Paper for ASSURE A25 – Develop Risk-Based Training and Standards for Waiver Review and Issuance: Task 1-2 Abbreviated Guidance was *Appendix A – Supplement to AC-2A As Appendix F*.

Form: Declarations
Applicant Guidance: This form lists common declarations with determine applicability of the framework and conformance to regulatory requirements.
Applicable Regulatory References:

- 14 CFR § 1 – Definitions and Abbreviations: https://www.ecfr.gov/current/title-14/chapter-I/subchapter-A/part-1
- 14 CFR § 107 – Small Unmanned Aircraft Systems: https://www.ecfr.gov/cgi-bin/text-idx?node=pt14.2.107&rgn=div5
- 49 USC § 40102 – Definitions: https://www.govinfo.gov/content/pkg/USCODE-2011-title49/pdf/USCODE-2011-title49-subtitleVII-partA-subparti-chap401-sec40102.pdf
- 18 USC § 2331 – Definitions: https://www.govinfo.gov/content/pkg/USCODE-2009-title18/pdf/USCODE-2009-title18-partI-chap113B-sec2331.pdf
- 18 USC §1001 – Statements or entries generally: https://www.govinfo.gov/content/pkg/USCODE-2015-title18/pdf/USCODE-2015-title18-partI-chap47-sec1001.pdf
- 18 USC § 3571 – Sentence of fine: https://www.govinfo.gov/content/pkg/USCODE-2010-title18/pdf/USCODE-2010-title18-partII-chap227-subchapC-sec3571.pdf

FAA Guidance: These are common declarations that assert applicability of the framework and the applicant's conformance to applicable regulatory requirements.


Declarations

Enter Declarations Information

a. The applicant is an institution or organization located in the United States, a State, the District of Columbia, or a territory or possession of the United States. * Yes No

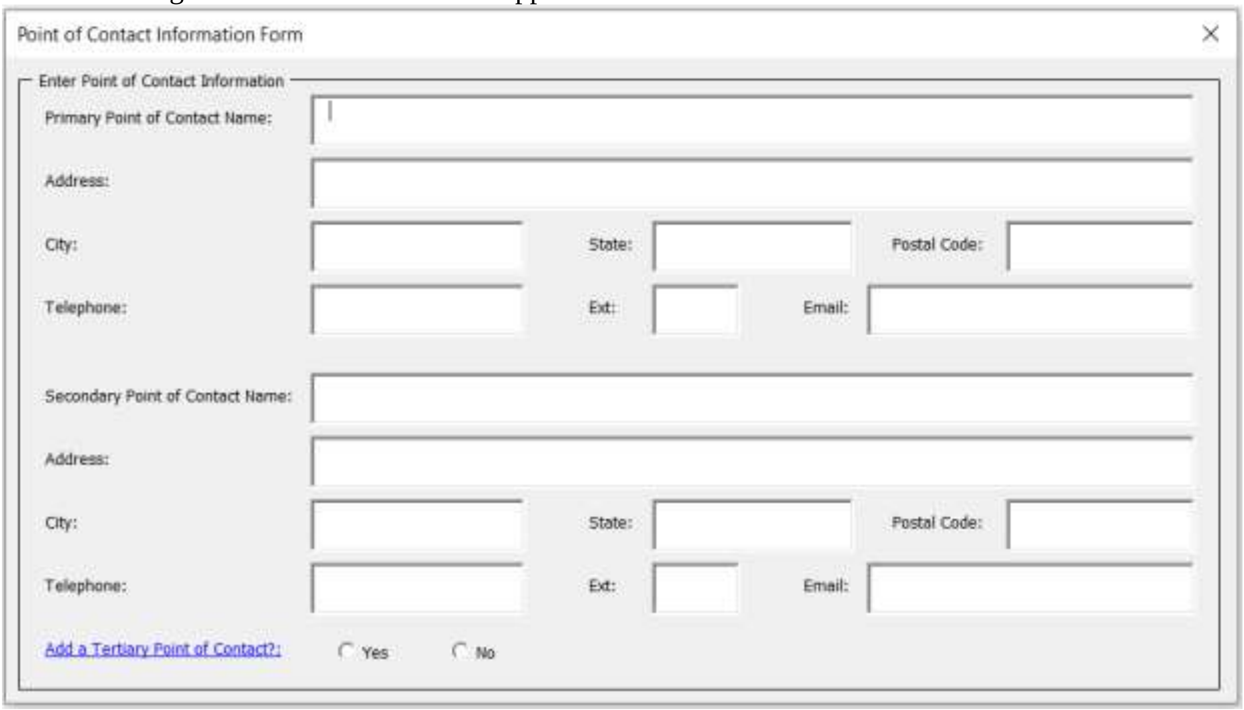
b. The operations described in this application meet the definition of civil (commercial) aircraft operations as defined in 14 C.F.R. § 1.1. Note: For guidance see Advisory Circular (AC) 00 1.1 Government Aircraft Operations. * Yes No

c. All flights made under the authority requested will be conducted under the limits of 14 C.F.R. § 107 with the exception of waivers granted for regulations under 14 C.F.R § 107.25. * Yes No

d. Whoever in any matter within the jurisdiction of any department or agency of the United States knowingly or willfully falsifies, conceals, or covers up by any trick, scheme, or device a material fact, or who makes any false fictitious, or fraudulent statements or representatives, or entry may be defined up to $250,000 or imprisoned not more than 5 year, or if the offense involves international or domestic terrorism (as defined in 18 USC § 2331), imprisoned not more than 8 years or both (as defined in 18 USC § 1001, 3571). * Yes No

e. Any information that is uploaded to this website is bound by the Freedom of Information Act (FOIA) and may be releasable. This requires compliance to FOIA and consent to the release of your information. If you do not consent to the release of your information you must contact us for further guidance. For more information, please visit http://www.foia.gov/. * Yes No

Form: Point of Contact Information Form
Applicant Guidance: This form lists points of contact within the institution/business/organization. It is intended to collect basic directory information for use by the FAA in establishing points of contact within the organization for the sake of maintaining communication throughout the waiver processing/approval process.
FAA Guidance: This form lists other directory information for an applicant's organization. Use this form for establishing a chain of contacts for the applicant.


Point of Contact Information Form

Enter Point of Contact Information

Primary Point of Contact Name:

Address:

City: State: Postal Code:

Telephone: Ext: Email:

Secondary Point of Contact Name:

Address:

City: State: Postal Code:

Telephone: Ext: Email:

Add a Tertiary Point of Contact?: Yes No

Form: Operational Description – Part 1
Applicant Guidance: This form serves to describe the proposed operation. Use this form to attach documentation that describes the listed elements of the proposed flight operations. Remember, detail is important, as the FAA needs to understand as much about the planned flight operations as possible. It is important to consider that the FAA must fully understand the nature of the operation and the associated hazards/risks.
FAA Guidance: This is where the applicant has their first opportunity to describe their operation. These attachments should include adequate detail to describe their operation.


Operational Description - Part 1

Enter Operational Description Information

PROGRAM EXECUTIVE SUMMARY:

Please include the following information:
1. Information about the organization and applicant:
   a. Description of historical and current experience with UAS operations
   b. Description of pilot training, certification, and experience
   c. Description of UAS maintenance training, certification, and experience
   d. Description of the organization's Safety Management System (SMS)

2. Brief description of intended UAS operations to include rationale as to why a waiver is necessary:

UAS OPERATIONS:

1. Operation strategy - Attach detailed descriptions for the items below:

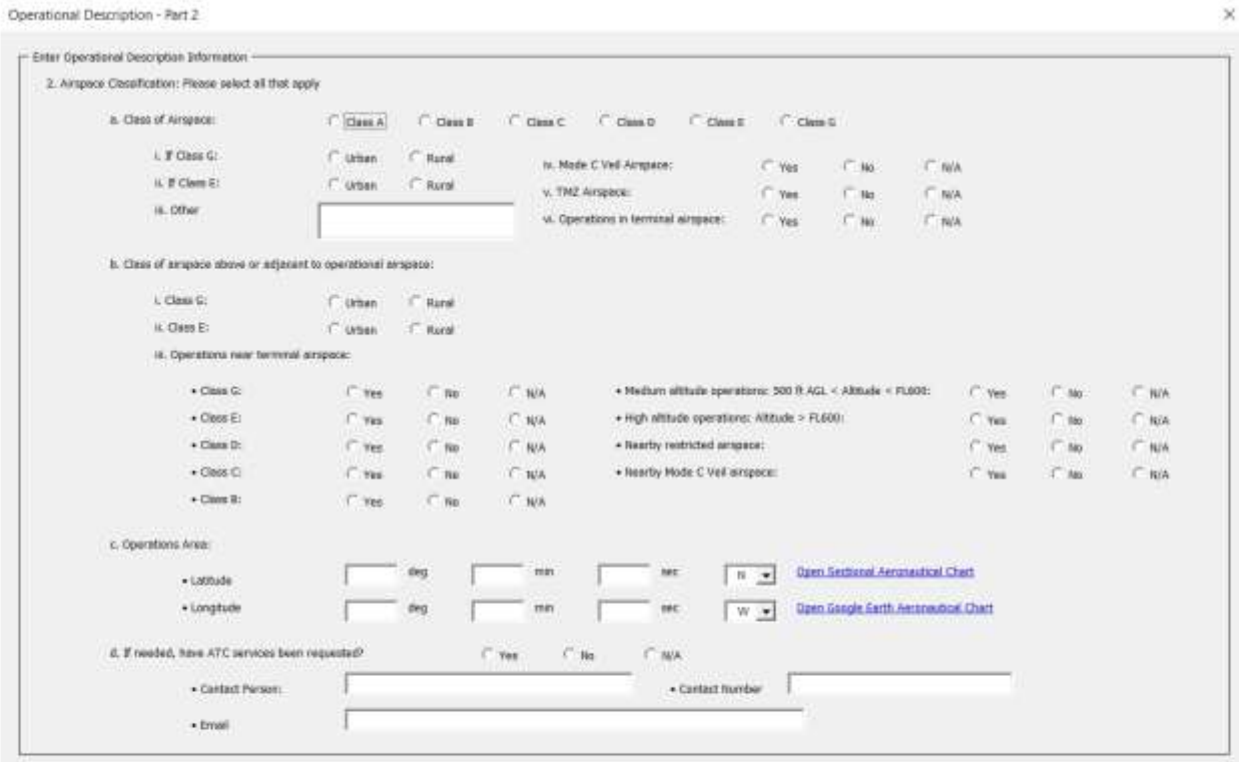
a. Site Survey: Attach File
b. Mission Planning: Attach File
c. Pre-Flight: Attach File
d. Launch: Attach File
e. En-Route: Attach File
f. Recovery: Attach File
g. Post Flight: Attach File
h. Emergency Operation: Attach File

Form: Operational Description – Part 2

Applicant Guidance: This form expands upon the operational description from the previous page. Indicate all classes of airspace that apply to the operation. The goal is to provide the FAA with an idea of the impact that the proposed operation will have on the airspace, to include a high-level depiction of what kinds of hazards an sUAS flight may encounter. For example, operations in class B, C, and D airspace will likely carry more risk than operations within class G airspace due to traffic volumes, airspace structures – i.e., instrument approaches and airspace boundaries, and Air Traffic Control (ATC) procedures. It is pertinent for the applicant to convey an accurate sense of the operation to the FAA regarding airspace and ATC requirements in the proposed operation area.

FAA Guidance: This form highlights the applicant's description of the operation area, to include airspace classes, a center point for the operation area, and ATC interactions* required for the operation.

*For the purposes of this guidance, it is assumed that ATC interaction with sUAS is a potential risk mitigation. The research team acknowledges that at present, ATC does not typically interact with sUAS operations.



Form: Operational Description – Part 3
Applicant Guidance: This form includes information regarding the type of operation and length (duration) of the flight operation. Be conservative here. If operating beyond visual line of sight (BVLOS) for any segment of the proposed operation, indicate "BVLOS" on this form. Similarly, indicate all that apply regarding day, night, or "light out" operations. This form also captures the duration of operations – i.e., how long will operations persist, and the approximate length of a given flight.
FAA Guidance: This form captures some of the more pertinent details regarding the applicant's proposed operation. This form helps to categorize the regulatory relief requested – e.g., BVLOS.


Operational Description - Part 3

Enter Operational Description Information

e. UAS Operations:

i. Type of Operation: VLOS BVLOS Other If other, describe:

ii. VFR (Required) *: Yes No If no, describe:

iii. Day Operation: Yes No N/A

iv. Night Operation: Yes No N/A

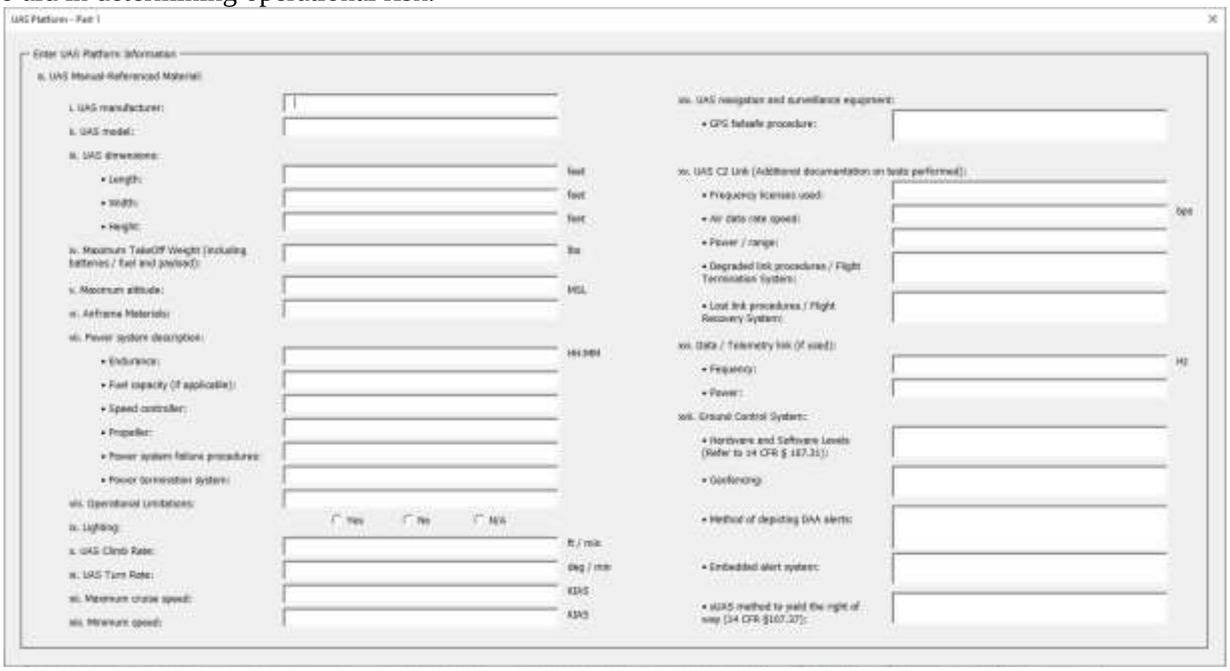
v. Light Out Operation: Yes No N/A

f. Length of Operational Period:

i. Provide detailed description on days/weeks/years:

ii. Duration of Flights:

Form: UAS Platform – Part 1
Applicant Guidance: This form captures detailed information about the unmanned aircraft and associated systems. It is important to rely on information from the manufacturer as much as possible. It is key that all information entered within this form be substantiated by reference to any system data that is provided by a reliable source such as the system manufacturer or a competent third party via testing. If data is derived via testing, please provide the FAA with necessary reports and data sets.
FAA Guidance: The applicant should provide relevant system information here. Data in this form should be as detailed as practical to describe their unmanned aircraft and associated systems to a satisfactory level to aid in determining operational risk.

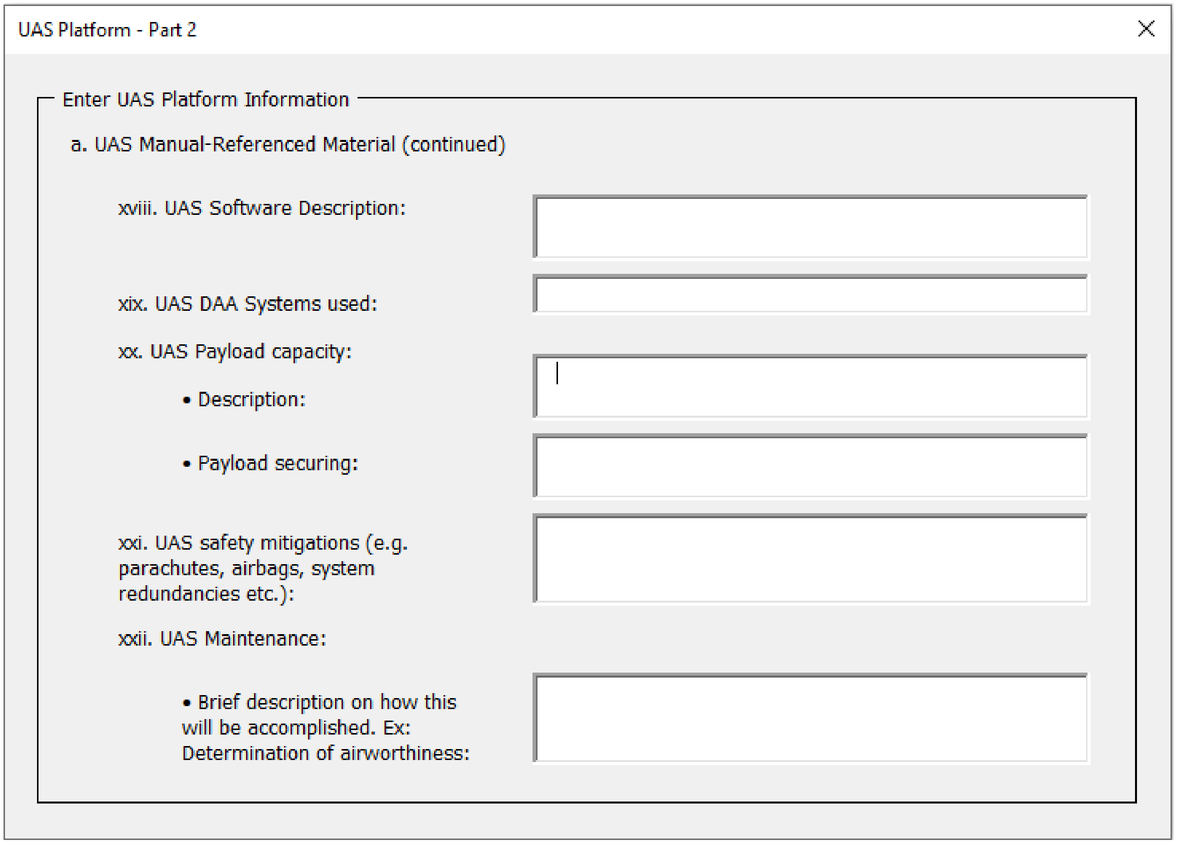


Form: UAS Platform – Part 2
Applicant Guidance: This form describes the UAS in greater detail, expanding upon software, payloads, safety systems, aircraft visibility, and total hours accumulated by the applicant on the system. Provide a detailed description of the data in these fields. It is important to rely on data from the system manufacturer or a competent third party to the greatest extent practical.
Applicable Regulatory References:

§ 107.31 – Visual line of sight aircraft operation: https://ecfr.io/Title-14/Section-107.31

§ 107.37 – Operation near aircraft; right-of-way rules: https://ecfr.io/Title-14/Section-107.37

FAA Guidance: Cross-reference applicant data with any available manuals or referenced data available via their submission.


UAS Platform - Part 2

Enter UAS Platform Information

a. UAS Manual-Referenced Material (continued)

xviii. UAS Software Description:

xix. UAS DAA Systems used:

xx. UAS Payload capacity:

- Description:
- Payload securing:

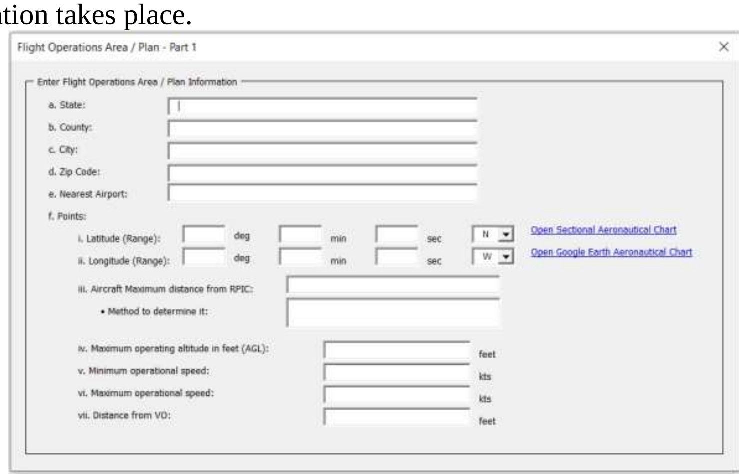
xxi. UAS safety mitigations (e.g. parachutes, airbags, system redundancies etc.):

xxii. UAS Maintenance:

- Brief description on how this will be accomplished. Ex: Determination of airworthiness:

Form: Flight Aircraft Qualifications
Applicant Guidance: This form captures important information regarding the flight crew. Input the required information in the fields to describe the level of experience and certification of the aircrew. It is important to consider that such things as remote pilot certifications, recurrent training, operational experience, robust aviation background, knowledge, and experience with the UAS used for the requested operation are all important. Remote pilot/aircrew training and experience is an important factor in mitigating operational risk. As such, be sure to accurately describe the remote pilot/aircrew's experience such that the FAA can determine their contribution to overall operational safety.
FAA Guidance: The applicant should list all necessary remote pilot/aircrew qualifications here. These qualifications should be commensurate with the level of risk associated with the proposed operation.

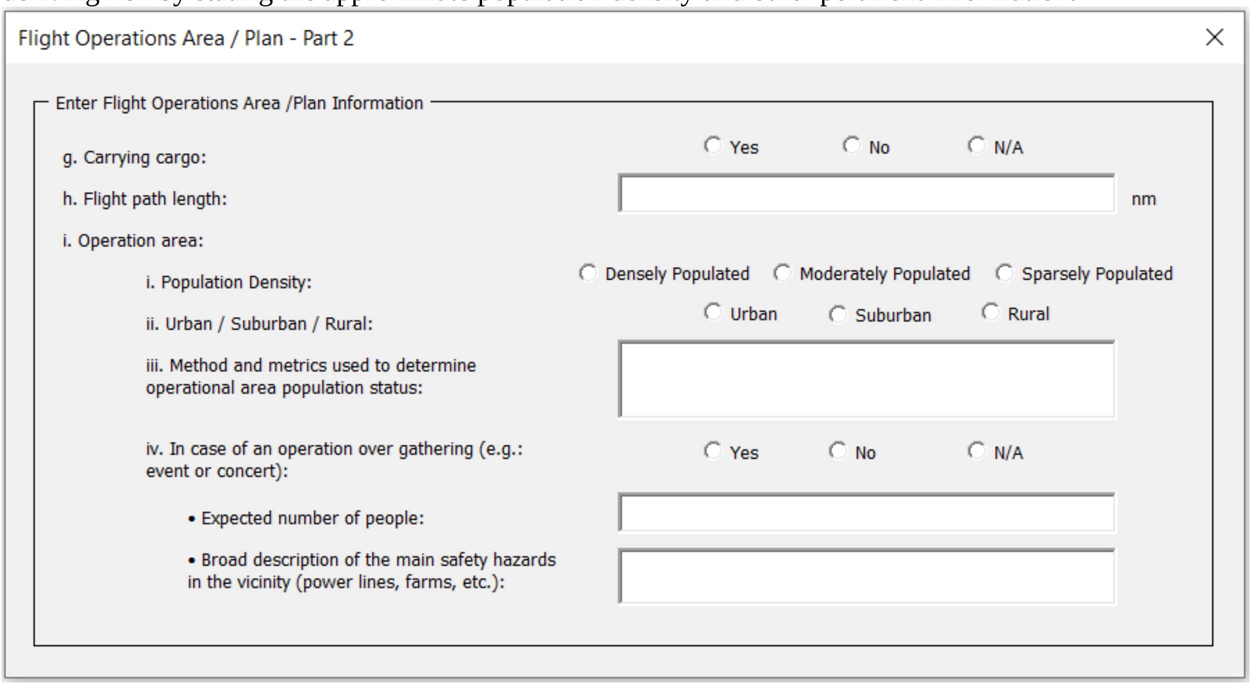
Form: Flight Operations Area/Plan – Part 1
Applicant Guidance: This form adds additional detail regarding the proposed operation area. It includes more specific information that helps the FAA to determine the risk associated with the operation. Hence, it is important to provide adequate reference for such things as population density. When describing the operation, use as much detail as practical to paint an accurate picture for the FAA of the proposed flight operation area.
FAA Guidance: This is an extension of the applicant's description of the operation area. It provides a basic idea of the operation area, nearest airport(s), and some of the important information regarding where the proposed flight operation takes place.



Form: Flight Operations Area/Plan – Part 2

Applicant Guidance: This form is a continuation of the flight operations area/plan. It includes additional information regarding the carriage of cargo, flight path length (if applicable), and additional information regarding the approximate population of the operation area. When including data regarding population density, ensure that the data has as high of a temporal resolution as practical. For example, indicating population density with census data may be inaccurate, as the census may be several years old. The goal of this form is to help the FAA understand *who* is subject to the risk associated with the operation and how it may affect the surrounding environment.

FAA Guidance: This is an extension of the applicant's description of the operation area. It should include additional detail regarding the type of environment – e.g., urban, rural, etc., and provide some context for deriving risk by stating the approximate population density and other pertinent information.


Flight Operations Area / Plan - Part 2

Enter Flight Operations Area /Plan Information

g. Carrying cargo: ○ Yes ○ No ○ N/A

h. Flight path length: [ ] nm

i. Operation area:

i. Population Density: ○ Densely Populated ○ Moderately Populated ○ Sparsely Populated

ii. Urban / Suburban / Rural: ○ Urban ○ Suburban ○ Rural

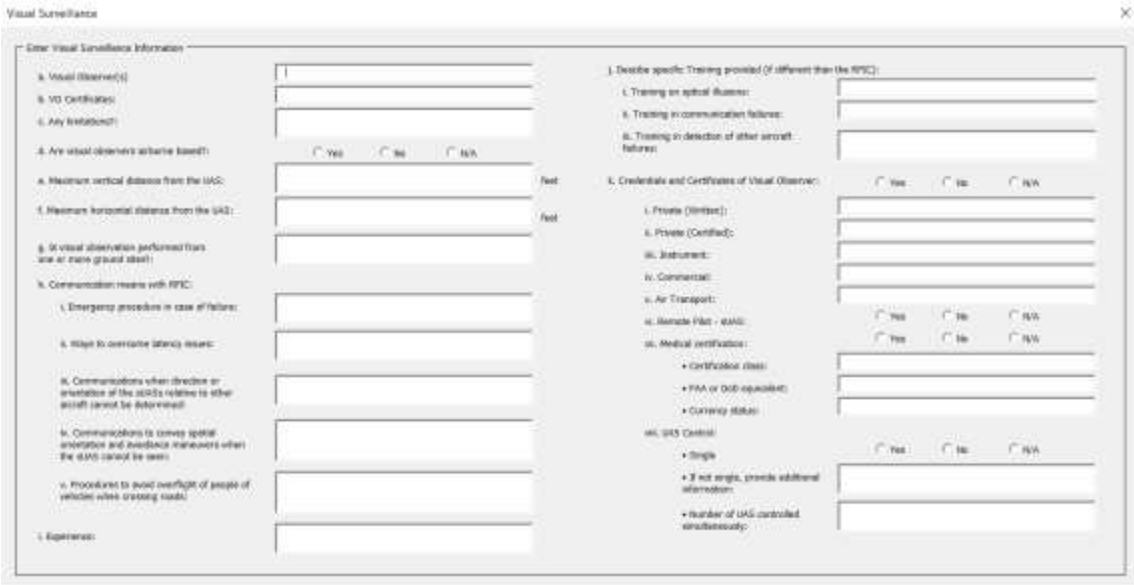
iii. Method and metrics used to determine operational area population status: [ ]

iv. In case of an operation over gathering (e.g.: event or concert): ○ Yes ○ No ○ N/A

• Expected number of people: [ ]

• Broad description of the main safety hazards in the vicinity (power lines, farms, etc.): [ ]

Form: Visual Surveillance
Applicant Guidance: This form is important, as it describes any visual observers (VOs that may be used for the proposed operation. Describe their position, credentials, experience, and any pertinent information on this form. It is important to provide the FAA with adequate detail to make a determination as to how the use of visual observer(s) may impact the safety of the proposed operation. Provide as much detail as practical to illustrate how/if visual observers contribute to operational safety.
FAA Guidance: The applicant's use of VOs is described here. It is important to consider the use of VOs and their impact on the overall level of operational risk.


Visual Surveillance

Enter Visual Surveillance Information

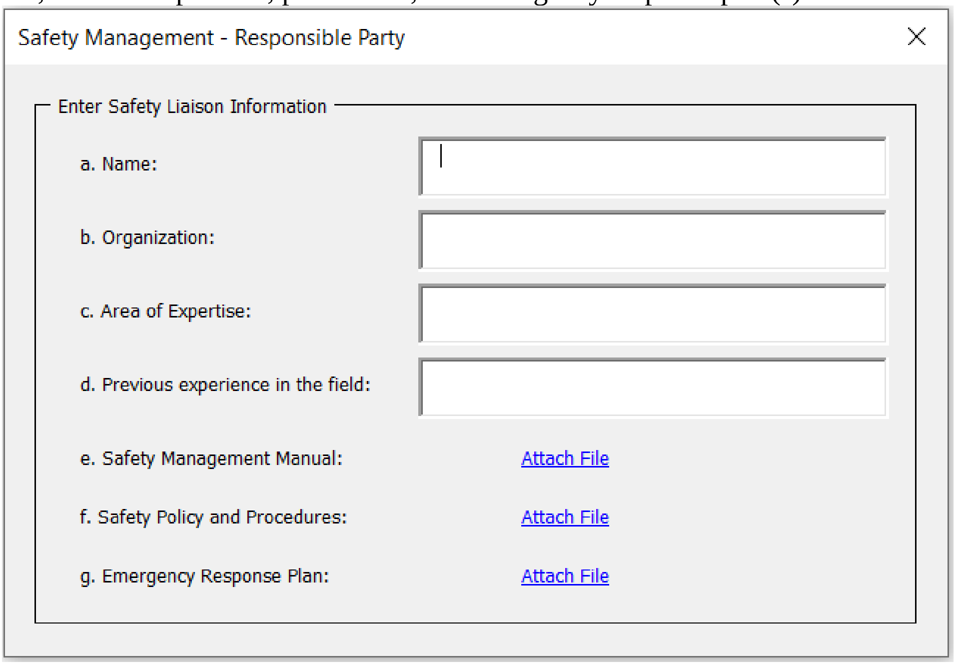
a. Visual Observer(s):
b. VO Certificates:
c. Any limitations?:
d. Are visual observers airborne based?: Yes / No / N/A
e. Maximum vertical distance from the UAS: Feet
f. Maximum horizontal distance from the UAS: Feet
g. Is visual observation performed from one or more ground sites?:
h. Communication means with RPIC:
i. Emergency procedure in case of failure:
ii. Ways to overcome latency issues:
iii. Communications when direction or orientation of the sUASs relative to other aircraft cannot be determined:
iv. Communications to convey spatial orientation and avoidance maneuvers when the sUAS cannot be seen:
v. Procedures to avoid overflight of people or vehicles when crossing roads:
i. Experience:

j. Describe specific Training provided (if different than the RPIC):
i. Training on optical illusions:
ii. Training in communication failures:
iii. Training in detection of other aircraft failures:
k. Credentials and Certificates of Visual Observer: Yes / No / N/A
i. Private (Written):
ii. Private (Certified):
iii. Instrument:
iv. Commercial:
v. Air Transport:
vi. Remote Pilot - sUAS: Yes / No / N/A
vii. Medical certification: Yes / No / N/A
• Certification class:
• FAA or DoD equivalent:
• Currency status:
viii. UAS Control:
• Single: Yes / No / N/A
• If not single, provide additional information:
• Number of UAS controlled simultaneously:

Form: Safety Management – Responsible Party

Applicant Guidance: Describe who "owns the risk" within the organization/business/institution. The safety liaison should be whomever is responsible for ensuring that the proposed operation is conducted safely and has full knowledge of all applicable safety practices and procedures associated with the proposed flight operation. This form includes submission fields for a safety management manual, policy and procedures, and an emergency response plan.

FAA Guidance: This form is a simple statement regarding the applicant's ownership and management of operational risk, to include policies, procedures, and emergency response plan(s).


Safety Management - Responsible Party

Enter Safety Liaison Information

a. Name:

b. Organization:

c. Area of Expertise:

d. Previous experience in the field:

e. Safety Management Manual: Attach File

f. Safety Policy and Procedures: Attach File

g. Emergency Response Plan: Attach File

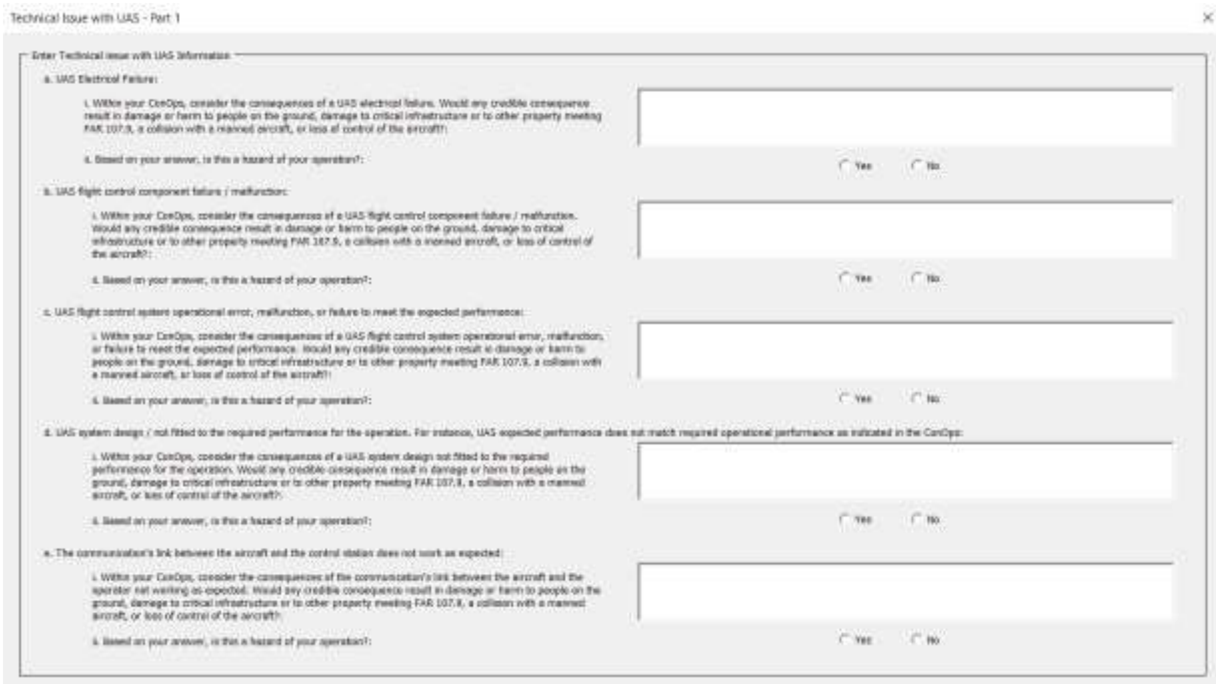
Forms:

1. Technical Issue with UAS – Parts 1 – 4: Captures information regarding system failures
2. Human Factors – Parts 1 – 4: Captures information regarding sources of human error/procedure
3. UAS Operations – Parts 1 – 4: Captures information regarding the operation itself

Applicant Guidance: The following series of forms are intended to aid the applicant and the FAA in determining the risks associated with the proposed UAS operation. The forms convey a detailed description of hazards/risks associated with various facets of the proposed operation relating to technical issues/failures within the UAS itself, human factors limitations, issues with liability, and security. It is important to be detailed and thorough here. The goal is to ensure that all claims regarding operational safety and risk are objective and able to be verified by reference to valid supporting data, regulatory precedent, or operation/system information wherever possible.

FAA Guidance: The applicant should provide adequate detail within these forms to make a determination of safety.

Technical Issue with UAS – Part 1


Technical Issue with UAS - Part 1

Enter Technical issue with UAS Information

a. UAS Electrical Failure:

i. Within your ConOps, consider the consequences of a UAS electrical failure. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

b. UAS flight control component failure / malfunction:

i. Within your ConOps, consider the consequences of a UAS flight control component failure / malfunction. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

c. UAS flight control system operational error, malfunction, or failure to meet the expected performance:

i. Within your ConOps, consider the consequences of a UAS flight control system operational error, malfunction, or failure to meet the expected performance. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

d. UAS system design / not fitted to the required performance for the operation. For instance, UAS expected performance does not match required operational performance as indicated in the ConOps:

i. Within your ConOps, consider the consequences of a UAS system design not fitted to the required performance for the operation. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

e. The communication's link between the aircraft and the control station does not work as expected:

i. Within your ConOps, consider the consequences of the communication's link between the aircraft and the operator not working as expected. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

Technical Issue with UAS – Part 2

Technical Issue with UAS – Part 3

Technical Issue with UAS – Part 4

Technical Issue with UAS - Part 4

Enter Technical issue with UAS Information

p. GCS total system failure - Software (Excluding power / electrical failure):

i. Within your ConOps, consider the consequences of a GCS total system failure - Software. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

q. GCS total system failure - Hardware (Excluding power / electrical failure):

i. Within your ConOps, consider the consequences of a GCS total system failure - Hardware. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

r. Not equipped with DAA or DAA not functional:

i. Within your ConOps, consider the consequences of an aircraft not equipped with DAA or DAA not functional. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the

ii. Based on your answer, is this a hazard of your operation?: Yes No

s. Airframe structural damage undetected before flying, for instance, from a previous rough landing:

i. Within your ConOps, consider the consequences of the airframe having a structural damage which has not been detected before flying. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or

ii. Based on your answer, is this a hazard of your operation?: Yes No

t. UAS not equipped with GBDAA or GBDAA non functional or out of range:

i. Within your ConOps, consider the consequences of a UAS not equipped with GBDAA or GBDAA non functional or out of range. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of

ii. Based on your answer, is this a hazard of your operation?: Yes No

Human Factors – Part 1

Note: This form captures information regarding maintenance, CONOPs, and other information.

Human Factors - Part 1

Enter Human Factors Information

PRE-OPERATIONS:

a. UAS not maintained by competent and / or proven entity:

i. Within your ConOps, consider the consequences of a UAS not maintained by competent and / or proven entity. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

b. UAS uninspected:

i. Within your ConOps, consider the consequences of not being able to ensure UAS inspection. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

c. UAS consistency with ConOps cannot be ensured:

i. Within your ConOps, consider the consequences of not being able to ensure consistency of the UAS operation with ConOps. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

d. Failure of protection from human errors:

i. Within your ConOps, consider the consequences of not being able to ensure the inspection of UAS. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

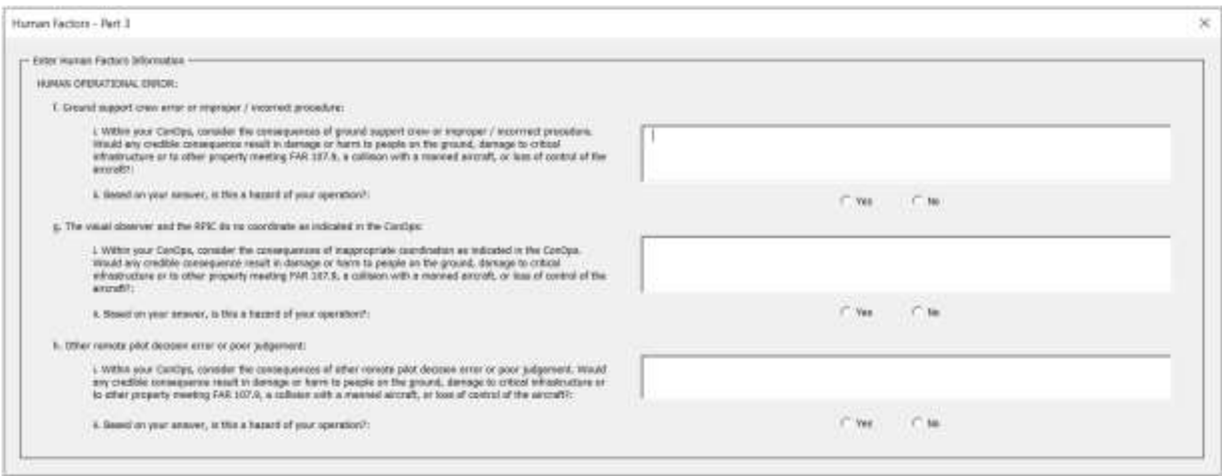
ii. Based on your answer, is this a hazard of your operation?: Yes No

Human Factors – Part 2

Note: This form addresses the impact of human error on overall operational safety.

Human Factors – Part 3

Note: This form is a continuation of Human Factors – Part 2



Human Factors – Part 4

Note: This form specifically addresses questions regarding the remote pilot and flight crew.

Human Factors - Part 4

Enter Human Factors Information

REMOTE CREW:

a. The operator has not been trained to follow the planned ConOps including emergency procedures:

i. Within your ConOps, consider the consequences of the operator not being trained to follow the planned ConOps including emergency procedures. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

b. Remote crew not trained in flights in adverse weather conditions. For example, not being able to determine when high winds occur nor understanding response of aircraft to high winds:

i. Within your ConOps, consider the consequences of a remote crew not trained in flights in adverse weather conditions. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

c. Remote crew unfit to operate (impaired by drugs / alcohol, etc.):

i. Within your ConOps, consider the consequences of the remote crew unfit to operate. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

d. Remote crew not experienced with the identification of critical environmental conditions:

i. Within your ConOps, consider the consequences of the remote crew not trained to identify critical environmental conditions (e.g. high winds, low visibility, high altitude etc.) Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

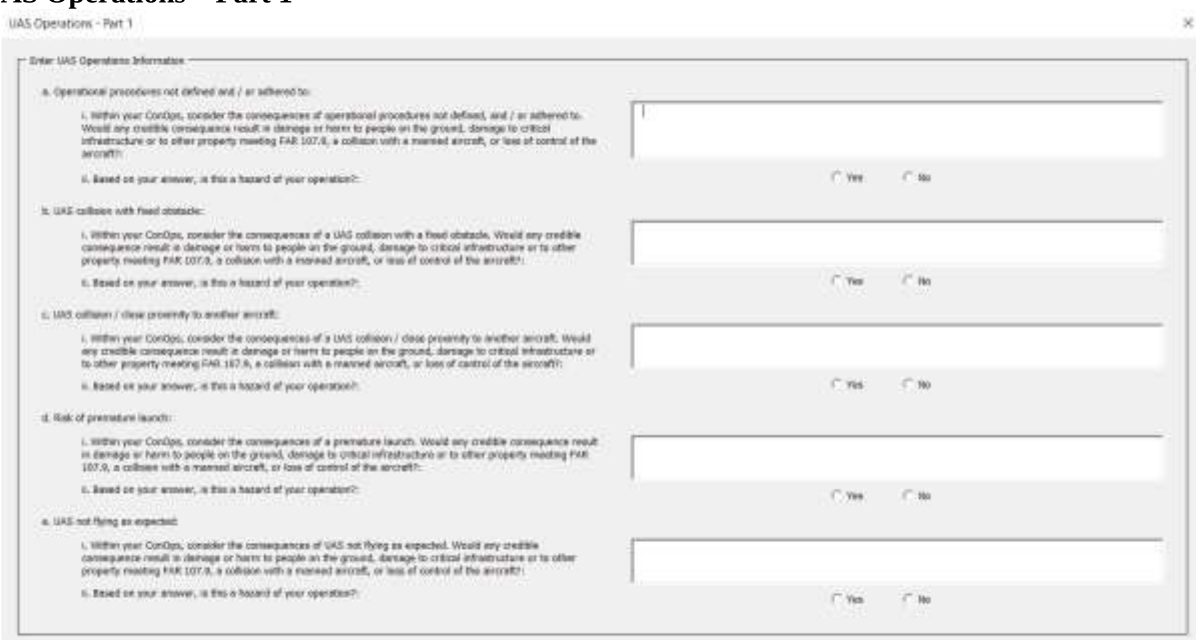
ii. Based on your answer, is this a hazard of your operation?: Yes No

e. Unauthorized personnel in GCS:

i. Within your ConOps, consider the consequences of unauthorized personnel in GCS. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

UAS Operations – Part 1



UAS Operations - Part 1

Enter UAS Operations Information

a. Operational procedures not defined and / or adhered to:

i. Within your ConOps, consider the consequences of operational procedures not defined, and / or adhered to. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

b. UAS collision with fixed obstacle:

i. Within your ConOps, consider the consequences of a UAS collision with a fixed obstacle. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

c. UAS collision / close proximity to another aircraft:

i. Within your ConOps, consider the consequences of a UAS collision / close proximity to another aircraft. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

d. Risk of premature launch:

i. Within your ConOps, consider the consequences of a premature launch. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

e. UAS not flying as expected:

i. Within your ConOps, consider the consequences of UAS not flying as expected. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

UAS Operations – Part 2


UAS Operations - Part 2

Enter UAS Operations Information

f. Atmospheric disturbance-wind / wind shear:

i. Within your ConOps, consider the consequences of atmospheric disturbance, such as wind or wind-shear. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

g. Flight beyond visual / radio line of sight:

i. Within your ConOps, consider the consequences of flight beyond the visual or radio line of sight. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

h. External supporting services to UAS are not consistent with ConOps indications. For instance, if certain weather forecast services are assumed to be provided, the external service does not provide weather forecast, or provides only partial information:

i. Within your ConOps, consider the consequences of external supporting services are not consistent with ConOps indications. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

i. No recovery from human error:

i. Within your ConOps, consider the consequences of a non-recovery from a human error. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

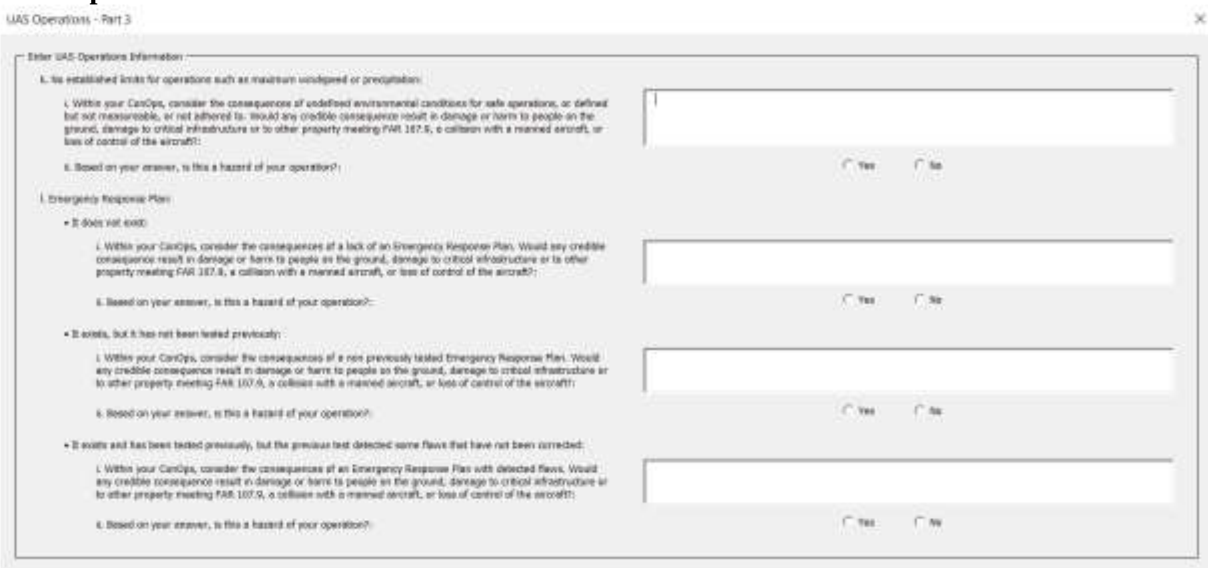
ii. Based on your answer, is this a hazard of your operation?: Yes No

j. Undefined operational procedures in adverse conditions, or not adhered to:

i. Within your ConOps, consider the consequences of undefined operational procedures in adverse conditions, or not adhered to. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of

ii. Based on your answer, is this a hazard of your operation?: Yes No

UAS Operations – Part 3


UAS Operations - Part 3

Enter UAS Operations Information

k. No established limits for operations such as maximum windspeed or precipitation:

i. Within your ConOps, consider the consequences of undefined environmental conditions for safe operations, or defined but not measureable, or not adhered to. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

l. Emergency Response Plan:

• It does not exist:

i. Within your ConOps, consider the consequences of a lack of an Emergency Response Plan. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

• It exists, but it has not been tested previously:

i. Within your ConOps, consider the consequences of a non previously tested Emergency Response Plan. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

• It exists and has been tested previously, but the previous test detected some flaws that have not been corrected:

i. Within your ConOps, consider the consequences of an Emergency Response Plan with detected flaws. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

REFERENCES

Federal Aviation Administration. (2021). *Advisory Circular 107-2A: Small Unmanned Aircraft Systems (sUAS)*. https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_107-2A.pdf

APPENDIX B – TASK 1-3: LOW-ALTITUDE RISK ASSESSMENT ROADMAP

Low-Altitude Risk Assessment Roadmap

October 30, 2020
Updated: January 23, 2022

NOTICE

Legal Disclaimer

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-xx/xx		

4. Title and Subtitle	5. Report Date
TITLE OF REPORT Develop Risk-Based Training and Standards for Waiver Review and Issuance: Literature Review: Task 1-3 (60) Day Roadmap	October 26, 2020 Revised: January 25, 2022
	6. Performing Organization Code ASSURE: University of North Dakota, Kansas State University, University of Alaska - Fairbanks
7. Author(s) Catherine Cahill, PhD, Tom Haritos, PhD, Paul Snyder, Timothy Bruner, Kurt Carraway, Gary Ullrich, Marcos Fernandez Tous	8. Performing Organization Report No.
9. Performing Organization Name and Address Univ. of Alaska Fairbanks 1731 South Chandalar Dr Fairbanks, AK 99775 Univ. of North Dakota 3980 Campus Rd Stop 9007 Grand Forks ND 58202-9007 Kansas State Univ. Polytechnic 2310 Centennial Road Salina, KS 67401	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 15-C-UAS
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Washington, DC 20591	13. Type of Report and Period Covered Roadmap 14. Sponsoring Agency Code

15. Supplementary Notes

The purpose of this research is to develop a roadmap for obtaining the data required for the development of industry standards that will form the basis of new rules and regulations as needed to conduct a low altitude airspace risk analyses for operations that do not fall under current rules. This research aims to identify the data categories required for the FAA to assess hazards and associated risk relative to a low-altitude airspace environment(s), to assess on-going or planned FAA research and standard-setting efforts with ASTM and RTCA, industry standards organizations, to determine what data is available for use in these efforts, in addition to identifying hazards and mitigations that may lend towards the development of a framework to conduct a low-altitude airspace risk assessment. The roadmap will include identifying the data categories required for the FAA to complete a low-altitude risk assessment, providing insight into what data exists and where it resides, determining what research applicable to this analysis is being conducted through current or upcoming FAA or industry standards efforts, and identifying gaps in required data.

17. Key Words	18. Distribution Statement
Safety Risk Management Low Altitude Airspace UAS Integration	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	46	

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Table of Contents

Table of Figures

List of Acronyms

Acronym	Meaning
ADS-B	Automatic Dependent Surveillance Broadcast
AGL	Above Ground Level
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ATC	Air Traffic Control
ATO	Air Traffic Organization (FAA)
ASDE	Airport Surface Detection Equipment
ASSURE	Alliance for System Safety of UAS through Research Excellence
ASTM	American Society for Testing and Materials, now ASTM International
BVLOS	Beyond Visual Line of Sight
CAASD	Centre for Advanced Aviation System Development (MITRE)
CFR	Code of Federal Regulations
CMS	Common Message Set
CONOPs	Concept of Operations
DEM	Data Elevation Models
DHS	Department of Homeland Security
DTED	Digital Terrain Elevation Data
EIA	Energy Information Administration
ERAM	En Route Automation Modernization
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
GA	General Aviation
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HIFLD	Homeland Infrastructure Foundation Level Data
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LAANC	Low Altitude Authorization and Notification Capability
LTE	Long Term Evolution
METAR	Meteorological Aerodrome Report
NAS	National Airspace System
NASR	National Airspace Resources
NEXRAD	Next Generation Radar
NGA	National Geospatial Intelligence Agency
NOAA	National Oceanic and Atmospheric Administration
NOP	National Offload Program
NORAD	North American Aerospace Defense Command
NPRM	Notices of Proposed Rulemaking
OE	Obstruction Evaluation

OSM	Open Street Map
PDARS	Performance Data Analysis and Reporting System
PSAP	Public Safety Answering Points
RADES	Radar Evaluation Squadron
RMSE	Root Mean Square Error
RTCA	Radio Technical Commission for Aeronautics
SMS	Safety Management System
SORA	Specific Operations Risk Assessment
STARS	Standard Terminal Automation Replacement System
TAF	Terminal Area Forecast
TCL	Technical Capability Level
TDWR	Terminal Doppler Weather Radar
TFR	Temporary Flight Restrictions
TRACON	Terminal Radar Approach Control
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAT	Universal Access Transceiver
UPP	UTM Pilot Program
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTM	UAS Traffic Management
VFR	Visual Flight Rules
VLOS	Visual Line of Sight

Executive Summary

As part of the ASSURE A25 research project, the FAA sponsor tasked the research team to develop a roadmap that outlines how unmanned aircraft systems (UAS) operators can gain permission to conduct low-altitude operations across the United States. Currently, UAS operators must conduct time and resource-intensive risk analyses to prove the safety of their operations in the National Airspace System (NAS) to obtain FAA approval to fly their missions. The FAA's recommended path to operations for the drone community is not to increase the amount of airspace analysis and ground population data provided by the FAA to conduct the needed risk analyses, but for the community to develop standards such as the Operations of Unmanned Aircraft Systems Over People (OOP) rule that, if met, will allow an operator to comply with applicable standards and obliviate the need for the intensive risk analysis. The intent of this roadmap is to provide information on what data is available and what research is being conducted that will assist in the development of standards for various UAS concepts of operations (CONOPs) and risk assessments for use by UAS operators conducting operations that do not fit easily under the current or future rules. Specifically, this report will: (1) identify data categories required for the FAA to complete a low-altitude risk assessment, (2) provide insight into what data exists and where it resides, (3) determine what research applicable to this analysis is being conducted through current or upcoming FAA or industry standards efforts, and (4) identify gaps in required data and suggest research to fill the gaps as able. Bearing this in mind, the scope of this roadmap focuses on unmanned flight operations at altitudes at or below 400 feet above ground level (AGL). Follow-on work could build upon this roadmap to address larger components of the FAA's envisioned "scalable compliance review process" that is aimed at establishing a flexible mechanism for obtaining operational approval based upon applicable rules and standards, and the operational risk associated with an unmanned aircraft system (UAS) for a given concept of operations (CONOPs).

The roadmap that follows was derived through a combination of subject matter expertise provided by the research team, targeted requests by the Commercial Drone Alliance (CDA), and knowledge gained from past and current research from the FAA's Center of Excellence (CoE) for UAS research, the Alliance for System Safety of UAS through Research Excellence (ASSURE). Therefore, this report includes a detailed overview of the past, present, and future research efforts through ASSURE that support low-altitude operations safety and informs the research team about what data is needed to develop industry standards and FAA rules and regulations that allow UAS operators to conduct missions without the need to conduct low-altitude risk assessment.

This roadmap represents a starting point for exploring critical data categories and components required for conducting low-altitude risk assessments and establishing the industry standards that will form the foundation of the rules needed to obtain operational approvals for UAS operations in the NAS at altitudes of 400 feet AGL and below. The team identified four key types of data categories needed for such a low-altitude risk assessment: air risk data (e.g., airspace class data, airborne traffic density, ADS-B participation, etc.), ground risk data (e.g., terrain, land use and zoning, population density, No Fly Zones, etc.), navigation/command and control data (GNSS availability, cellular tower coverage, satellite communications availability), and weather considerations data (e.g., current and forecast weather data, weather radar coverage as a function of height, etc.). Industry standards must account for the variety of data availability and environmental conditions encountered during flights to ensure the safety of the NAS. Additionally,

the FAA rules need to allow for the continued use of risk analyses for operations that do not fall neatly under the rules.

This report includes representative data sets for each of the identified data categories and a visual representation to highlight key categories that have been captured through this work. Additionally, this report demonstrates where data can be obtained and data that may be difficult to obtain. Most importantly, identifying specific data elements inside these data categories and establishing consistency among the data sets and data elements will provide a solid foundation for the development of (1) standards and practices for low-altitude operations and (2) policy regarding low-altitude UAS operations. Standards and rules that address the environmental conditions described by the elements of the roadmap, when combined with certified aircraft and the standardized training of airmen, will result in safer, low-altitude UAS operations.

INTRODUCTION AND SUMMARY

The National Academies of Science, Engineering, and Medicine (NASEM, 2018) suggests the Federal Aviation Administration (FAA) should expand on quantitative data collection to address risk as it pertains to unmanned aircraft systems (UAS) integration as the qualitative nature of current risk management approaches implemented to address UAS risk creates results that fail to be repeatable, predictable, scalable, and transparent. At present, the lack of empirical data in the UAS industry leads to qualitative and subjective risk assessment and analysis greatly reducing the probability for expanded and non-segregated operations in the National Airspace System (NAS). Additionally, NASEM (2018) ascertains an explicit need for the FAA to evolve away from the subjectivities presented in FAA order 8040.4B (Safety Risk Management Policy, 2017) related to UAS and migrate towards quantitative probabilistic risk practices based on acceptable safety risk utilizing well-quantified data that is relevant. The development of industry safety standards and rules based on those standards provides a route to operational approval that minimizes the risk of a UAS operation and greatly reduces the burden of conducting an operational risk assessment based on FAA order 8040.4B (or 8040.6) because parts of the operation have already been classified as safe. The standards and rules paths are the FAA's preferred method for UAS operators obtaining operational approvals, and several rules governing UAS operations have been successfully promulgated during the last several years.

In 2016, the FAA amended its regulations to Title 14: Aeronautics and Space and added part 107: Small Unmanned Aircraft Systems. The passage of 14 CFR part 107 provided rules to conduct low risk unmanned aircraft operations in the National Airspace System, greatly enabling commercial and the public sector. At that time, a large majority of UAS operations fell within the restrictions of part 107 (i.e., aircraft under 55 pounds, daylight, ops below 400 feet AGL). Although a noteworthy effort on the part of the FAA to implement sUAS regulations, further research is deemed necessary to address issues that remain unresolved. Issues hindering the integration of larger systems as identified by the GAO (2012) include: (1) the inability for UAS to detect, sense, and avoid other aircraft and airborne obstacles, (2) vulnerabilities in the command and control paradigm, (3) limited human factors engineering incorporated in UAS technologies, (4) lack of standards to guide the safe integration of UAS, and (5) the lack of capability to transition UAS into the Next Generation Airspace System (NextGen). Resolution of these issues are key to the safe and effective full-scale integration of UAS into the NAS regardless of vehicle size and weight.

Fortunately for sUAS operations, 14 CFR part 107 provides opportunities for operators to apply for waivers to specific provisions of the basic regulation, such as flying beyond the visual line of sight (BVLOS) of the Pilot in Command or operating the UAS over people. These waiver provisions afford applicants the ability to petition the FAA for increased operational latitude, while providing the FAA with a mechanism to closely review all waiver requests to ensure that the proposed UAS flight operation does not compromise the safety of the NAS. The increasing level of risk associated with the advanced operations, such as BVLOS and operations over people, requires that the FAA carefully evaluate these operations to ensure the safety in the NAS as multiple operators and organizations conduct an increasing number and variety of advanced operation types.

According to 81 FR 50789 (Requests for Waivers and Authorizations Under 14 CFR part 107 System of Records Notice, 2016), the waiver application and review process depend on the complexity of the operation, the completeness of the applicant's waiver documentation, the justification for the operation, and the data needed for the waiver team to evaluate if the operation can be performed safely. The amount of documentation accompanying a waiver submission should be proportional to the scope and scale with which the applicant seeks relief from a given regulatory element of part 107. In the simplest terms, if an applicant seeks to waive more elements of part 107 that result in a greater level of operational risk, they must provide more substantial documentation and rationale behind their justification(s). The wide range of differences in operator experience, aircraft types, aviation knowledge, and organizational maturity add complexity to the problem. Therefore, the required documentation needs to include an analysis of the risks associated with the airspace (including air and ground risks), aircraft, and airmen and proposed methods for mitigating the identified risks. Obtaining sufficient data on all three aspects of the safety case is a challenge to many operators, so this requirement has been the downfall of many waiver requests.

The FAA has a division specifically assigned to evaluate the safety case documentation for waiver requests and continues to advance their reviewing processes as data and research become available. However, many of the UAS operators requesting waivers do not have the aeronautical expertise required to assemble a viable safety case. This presents a challenge for the FAA personnel assigned to review the safety cases and frustrates industry stakeholders seeking authorization for operational latitude outside the provisions established as 14 CFR part 107 who do not understand what needs to be included in the risk assessment.

The most challenging part of developing a safety case is the characterization of risks associated with the UAS. Very few UAS are type certified, so the FAA personnel evaluating the UAS need data from the operator establishing the aircraft's durability and reliability, the robustness of the command and control links, the sense and avoid methods used to avoid other aircraft, the lost link procedures, the maintenance protocols, the ability to maintain continuity of flight after an engine failure, the potential damage due to the aircraft striking a human (for operations over people) or vehicle, the temperature and wind limits of the aircraft, and a multitude of other information. This information is difficult to obtain even for seasoned UAS operators but is essential for evaluating the potential for safe flight during advanced operations. Standards bodies are working to develop consistent standards for the safety of the aircraft and aircraft components that will ease this burden. The FAA also is working toward a simplified method for obtaining type certification that will allow operators to meet safety requirements without conducting potentially prohibitively expensive testing.

UAS operators also need to demonstrate in their safety cases the training credentials and expertise of their crew and the policies and procedures that will limit human error during operations. NIST, universities, and other organizations are developing training and certification programs for UAS pilots; however, many operators requesting advanced operation waivers only possess a Remote Pilot Certification and never received hands-on training on how to safely plan flights, including implementing emergency procedures, maintain their aircraft, prevent fatigue from influencing their decisions, and other activities required by the airman to conduct safe operations. These operators need to demonstrate to the FAA waiver evaluators that they are professionals who understand the implications of flying a UAS in the NAS and will ensure the safety of their operations or meet new standards for crewperson training to ensure the safety of flights under their command.

Lastly, the risk assessment must evaluate the risks associated with the UAS's operating environment. The waiver applicant must be able to demonstrate that the UAS can operate in a specific environment while reducing the risk to the lowest practical level. As operators want to conduct missions that are longer distance, BVLOS, and/or over people, they must show that they are managing the risk to everyone in that environment. The operator can do these one of two ways: by showing compliance with industry standards and FAA rules, or by obtaining the environmental data and demonstrating that the risk of the operation is sufficiently low to meet regulatory intent. It is important to note that the analysis of the risk must address whether the aircraft and operation meet the intent of the spectrum of regulations governing UAS operations such as CFR 14 Part 91.113, that requires the UAS to possess systems that will allow the operator and/or aircraft to see and avoid other aircraft, and not just be based on big sky theory, the idea that the risk of collision is so low because there are so few aircraft in the area that safe flights can occur. A Detect and Avoid (DAA) system, a ground-based or airborne system that allows a UAS operator to sense and avoid other aircraft, that meets industry standards will help ensure that a collision between aircraft will not occur. In contrast, the purely probabilistic calculations included in a big sky theory analysis can be manipulated to give the operator a reasonable risk level on paper that does not actually prevent a collision.

UAS operators seeking to show that the risk of their operation is low, find it difficult to obtain the data needed. Examples include demonstrating validating the population density is low over the entire flight path, an aircraft flying within 50 feet of high-tension powerlines should not be a risk factor for manned aircraft or demonstrating the weather should not be a factor during a given season. UAS operators can spend significant effort and resources to obtain the data needed to prove the safety of their operation in a specific environment; then they change environments and have to go through the process for the new location. As a result, there is a push from industry stakeholders for the FAA to develop a quantitative method for assessing the risk of an operation anywhere in the country. The initial request from industry representatives is that:

> "...the FAA and other relevant stakeholders conduct a sophisticated, national study of the operational risks associated with low-altitude UAS operations below 400 feet AGL. The risk analysis would consider factors such as traffic density, trajectories, weather, population density, terrain, land use and zoning, building heights, and other local factors for the entire United States. The federal government could conduct an airspace characterization effort leveraging nationwide radar and other surveillance assets (from the FAA, DOD, and other sources) to provide an assessment of the relative risk presented by UAS operations (including piloted urban air taxis) within this low-altitude airspace environment. The study would leverage available data to assess the level of risk on a probabilistic basis.
>
> Although useful for all UAS operations beyond visual line of sight (BVLOS), the study would be exceptionally helpful in unlocking low-altitude, low-risk operations masked by existing infrastructure and terrain features—operations that promise to provide significant utility to public safety and other enterprises facing staffing shortages and social distancing

constraints. The study would also be extremely useful to enable UAS delivery operations more broadly, including for delivery of critical supplies to quarantined individuals."

A low-altitude risk assessment of this type would provide a much-needed way for a UAS operator to quickly obtain the data needed to quantifiably assess the risks associated with the environment in which their low-altitude UAS operations would occur. However, this effort would be time and resource intensive for the FAA, and it is not sufficient on its own to guarantee the safety of the UAS operation. As stated above, the UAS operator would still need to assess the risks due to the UAS, the airmen associated with the operation, and the changing environment to determine the risk of the operation. The study could provide a common basis for evaluating one part of the safety case needed for the FAA to evaluate and approve an advanced operations waiver, but the FAA's preferred method for obtaining operational approvals is to have the operator comply with a rule that points to industry safety standards. Complying with the rule reduces the risk of the operation to a level deemed safe by the FAA and negates the need for complex risk assessments except in cases of novel or complex operational types.

The work described in this document outlines a roadmap for obtaining the data needed to develop industry safety standards and rules governing low-altitude operations below 400' AGL in the NAS or for a more advanced operator to conduct a risk assessment for an operation that does not fall under one of the promulgated rules. The effort is not a thorough gap analysis and will not identify the specific data variables for each data category required to complete a low-altitude risk analysis, understanding, mitigation, or standard development. However, it will be a roadmap for obtaining the data required to do so. The roadmap will include identifying the data categories required for industry standards bodies to develop standards or operators to complete a low-altitude risk assessment, providing insight into what data exists and where it resides, determining what research applicable to this analysis is being conducted through current or upcoming FAA or industry standards efforts, and identifying gaps in required data and suggesting research to fill the gaps.

This task is focused on segregated airspace (under 400' AGL), but the gaps and lessons learned during this effort may be applied to follow-on studies, and future effort may also be focused on the development of a 'scalable compliance review process' for low-level integrated airspace (400'-3000 'AGL).

The path to obtaining the data needed for standards development or providing the FAA with the information needed to review a safety case for an operation not covered by a rule is as follows:

- Identify the data categories required for the FAA to assess hazards and associated risk relative to low-altitude airspace environment(s) to assess safety case submissions more effectively.
    - Possible data categories would include traffic density, trajectories, weather, population density, terrain, land use and zoning, building heights, and other factors for the entire United States.
    - The safety risk assessment would be in accordance with FAA Safety Risk Management Policy 8040.4B, FAA Unmanned Aircraft Systems Safety Risk

Management Policy 8040.6. The assessment would limit the data categories related to those under the jurisdiction of the FAA.

- Identify current, readily available sources of data related to these categories.

- Identify where data currently is unavailable for these categories.

- Assess ongoing or planned FAA research and standard-setting efforts with American Society for Testing and Materials (ASTM), now called ASTM International, and Radio Technical Commission for Aeronautics (RTCA), industry standards organizations, to determine what resulting data may be used to fill the data gaps for these categories. Include dependencies between research activities.

- Identify remaining gaps between the current and expected data where no FAA research or industry standards efforts are identified and identify what data is needed for the industry to develop safety standards or operators to complete safety risk assessments in relation to low-altitude airspace environment.

- Suggest research to fill the data gaps or, if research and testing is not feasible, the studies that should be conducted to assist the FAA in assessing the impact of specific risks and developing rules.

This process should, with enough time and support, provide a useful tool for industry standards bodies to develop standards and UAS operators to gain operational approvals by complying with a rule based on safety standards or seeking to conduct advanced operations and needing to produce advanced operation safety cases.

Low-Altitude Risk Assessment Roadmap

Research Background

The FAA possesses a research portfolio that feeds standards, rules, and regulations development and impacts the low-altitude operations risk assessments that are a source of concern for the UAS industry. UAS industry stakeholders generally are unfamiliar with the research efforts being conducted at the FAA's William J. Hughes Technical Center, in the FAA's Center of Excellence for UAS Research, and under other FAA programs. The knowledge originating from these research efforts is being included in standards bodies' analysis as it becomes available and will influence the development of the standards identified as most important by industry. This report will address the research most readily accessible to industry stakeholders and being included in standards development by academic research participants, that done by the FAA's Center of Excellence for UAS Research.

The Consolidated Appropriations Act of 2014 served as a congressional mandate and directed the Federal Aviation Administration (FAA) to establish a Center of Excellence (COE) for unmanned aircraft systems (UAS). In May 2015, the FAA selected the Alliance for System Safety of UAS through Research Excellence (ASSURE) as the FAA's new UAS COE. Research conducted under the auspices of the COE is designed to address current gaps associated with UAS technologies and integration of UAS into the National Airspace System (NAS), as well as support the development of policy and standards required to address new and innovative aspects for expanded and non-segregated UAS flight operations. The UAS industry has limited familiarity with ASSURE efforts to test and evaluate UAS technologies, establish safe concepts of operations for specific advanced operations, conduct safety analyses, collect data for use in models and simulations, forecast future use and economic impacts, and explore other factors that will allow standards bodies to develop new standards, UAS operators to conduct operations more safely, and the FAA to regulate UAS use, including low-altitude operations, in the NAS. Therefore, the following section of this roadmap highlights past, current, and future ASSURE projects and ASSURE coordination with standards bodies that support low-altitude operations safety and forecasting.

<u>Past Research (ASSURE)</u>

Since research through the FAA's CoE began in 2015, there have been numerous research projects that have set the stage for current, ongoing research projects. This section provides a brief overview of past ASSURE research, providing a high-level discussion of research objectives and a brief discussion of outcomes. Individual reports and project discussions are available form ASSURE's website (assureuas.org).

FAA Research Requirement: Certification Test Case to Validate sUAS Industry Consensus Standards (**A1**)

UAS Research Focus Area: UAS Airworthiness and certification

ASSURE A1 sought to address the use of consensus standards from ASTM F38 for use in establishing a certification basis for sUAS through 14 CFR part 21.17(b). As such, research for A1 focused on an in-depth analysis of ASTM F2910-14: Standard Specification for Design and

Construction of a Small Unmanned Aircraft System (sUAS). The focus of this research was to identify compliance issues and gaps within the standard and determine how these standards could inform a flight test program. Ultimately, this research helped to inform revisions to F2910 and the development of F3298: Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS).

FAA Research Requirement: Small UAS Detect and Avoid Requirements Necessary for Limited Beyond Visual Line of Sight (BVLOS) Operations (**A2**)

UAS Research Focus Area: BVLOS and Detect and Avoid (DAA)

ASSURE A2 explored requirements for BVLOS flight operations as they pertained to sUAS. This research included a literature review of pilot and ground observer see and avoid performance, recommended performance measures for FAA, a survey of various technologies for DAA, general assessment for risk associated with the use of DAA technologies, and considerations for flight testing. This research enabled future operational testing of DAA systems by identifying key hazards associated with BVLOS flight operations, contributing to inputs for risk assessments for BVLOS flight operations, and recommending additional controls. Flight tests served as a mechanism to validate preliminary data gathered as a result of this work. Outcomes of this research informed additional (ongoing) ASSURE research into the exploration of DAA performance measures.

FAA Research Requirement: UAS Airborne Collision Hazard Severity Evaluation (**A3**)

UAS Research Focus Area: Airborne collision and severity

Research through ASSURE A3 focused on determining the potential severity of UAS with manned aircraft to identify an Equivalent Level of Safety (ELOS) to manned aviation. This was accomplished by extensive use of complex simulations to explore the effects of the collisions of manned/unmanned aircraft of various types/configurations. The outcomes of this research provided data regarding damage that may occur as a result of a manned/unmanned aircraft collision. Additionally, it informed the need for future work – to include an exploration of engine ingestion.

FAA Research Requirement: UAS Maintenance, Modification, Repair, Inspection, Training, and Certification Considerations (**A5**)

FAA Research Focus Area: UAS maintenance and modification

ASSURE A5 explored requirements for UAS maintenance, modification, repair, inspection, and maintenance technician repair and certification. This research explored existing maintenance programs for commercial UAS, performed an analysis of current maintenance technician programs and made comparisons to existing aircraft maintenance paradigms for manned aviation. Outcomes of this research answered questions relating to existing maintenance practices for UAS, identified critical maintenance considerations for UAS with respect to technical qualifications, and proposed future research regarding the need for reliability data and the need to understand maintenance-induced failures.

FAA Research Requirement: UAS Surveillance Criticality (**A6**)

FAA Research Focus Area: Detect and Avoid (DAA)

This research focused on addressing UAS surveillance and sought to analyze UAS surveillance technologies and methodologies against industry standards. As part of this research, the team explored questions relating to how ADS-B (out) may impact UAS DAA functions, design assurance criteria for UAS DAA functions, and criteria for evaluating equivalent level of safety of UAS when compared to manned aircraft DAA functions. Outcomes of this research informed further research into FAA surveillance criticality analysis and provided a starting point for evaluating the performance of DAA technologies against standards and other systems.

FAA Research Requirement: UAS Noise Measurement (A8)

FAA Research Focus Area: UAS Noise certification

This research gathered noise data on a Tiger Shark UAS for the purpose of outlining standards for gathering noise data for UAS noise certification. As part of this research, The FAA's Office of Environment and Energy (AEE) carried out a test program at Griffiss International Airport in Rome, NY. Outcomes of this research were test data and methodologies for gathering noise data for UAS.

FAA Research Requirement: UAS Recommendations for Minimum UAS Control Station Standards and Guidelines (**A10**)

FAA Research Focus Area: Control Stations and Human Factors

ASSURE A10 focused on the development of recommendations for minimum control station requirements regarding controls station design and human factors. This research effort was divided into control station (CS) subtasks and pilot and crew (PC) subtasks with the goals of merging functional requirements and human factors considerations developed as part of the CS tasks with operational requirements and procedures for pilots that were developed as part of the PC tasks. Ultimately, the outcomes of each set of subtasks were intended to inform the design and operation of a UAS control station with human factors considerations – e.g., providing guidance for ergonomics required for the safe operations of a UAS.

It is important to note that this research emphasized UAS that were operated beyond "small" designation; with maximum takeoff weights greater than 55 pounds. Initial assumptions for the PC subtasks 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.

To link PC subtasks with those of the CS team, researchers for the PC tasks performed validations of PC tasks on representative control stations, documented the findings, and revised pilot procedures accordingly.

FAA Research Requirement: UAS Low Altitude Safety Case Study (**A11**)

UAS Research Focus Area: Operations over people and ground impact metrics

ASSURE A11 focused on exploring data requirements and analysis required for the submission of a waiver for operations over people for 14 CFR part 107. This research consisted of exercising the part 107 waiver process by investigating requirements to meet performance standards established by the UAS Micro-ARC. Outcomes of this research include the successful acquisition of a waiver to operation a DJI Phantom 3 over people as well as new methodologies for establishing safety thresholds for UAS operations over people.

FAA Research Requirement: UAS Ground Collision Severity Evaluation 2017-2019 (**A14**)

UAS Research Focus Area: Ground collision and severity

Research through ASSURE A14 emphasized the validation of earlier ASSURE research regarding ground impact severity through ASSURE A4 (not listed here) and ASSURE A11. This research included the evaluations of kinetic energy released through UAS ground impacts via impact testing and correlating that data with established injury metrics. Outcomes of this research provided recommendations for areas of additional testing, assessments of the efficacy of injury metrics, and recommendations for performance-based standards for securing components.

Current Research (ASSURE)

FAA Research Requirement: Small UAS Detect and Avoid Requirements Necessary for Limited Beyond Visual Line of Sight (BVLOS) Operations **(A18)**.

UAS Research Focus Area: Low Altitude Operations Safety

By 2014, even before the FAA had created rules for the operation of sUAS, there were numerous safety reports of close encounters between sUAS and manned aircraft. These encounters generally are occurring when manned aircraft are close to the ground during approach and landing. With the release of the 14 CFR part 107 sUAS rule, the number of UAS in the NAS has increased dramatically, increasing the probability of close encounters and midair collisions. DAA technology is not only necessary to help manage this risk, but also to allow BVLOS operations. Standards and rules for DAA that will allow UAS to conduct BLVOS operations in the future. Many sUAS operations, such as precision agriculture, crop and wildlife monitoring, search and rescue, and linear infrastructure inspection are currently restricted, limiting the potential of sUAS commercial operations and public benefit.

This research will help inform FAA regulations and industry standards addressing DAA and BVLOS operations. Some of the questions this research intends to answer are:

- What are the use cases requiring DAA for BVLOS operations?
- What DAA systems are available, what are their capabilities and limitations, and are they mature enough to support BVLOS operations?
- Is the SARP definition of "Well Clear" appropriate?
- What characteristics of DAA systems and UAS must be considered to ensure maintenance of well clear status?
- How should sUAS DAA systems be evaluated to ensure they provide safe separation services in the NAS?
- What is the recommended test method(s) to evaluate different DAA systems?

FAA Research Requirement: UAS Test Data Collection and Analysis **(A19)**.

FAA Research Focus Area: Low Altitude Operations Safety

This research relates to the development of the technical data requirements, test methods, risk assessments, safety risk management processes, data collection, and administrative processes/reporting used to inform safety cases in support of the UAS integration regulatory framework. It will develop a system to capture test objectives and categorize them consistent with the FAA's UAS Integration Research Plan functional areas and research domains. The analysis of this data will inform the development of regulatory products (i.e., rules, standards, policy, etc.) needed to reach UAS integration milestones. Finally, it will facilitate the query and reporting of data in a consistent format across the Test Sites.

To enable development of safety cases, this system must:

1. Provide a framework for developing/supporting UAS integration safety cases by utilizing test objectives and data.
2. Align UAS test objectives and data to:
    a. Research objectives in a manner that enables users to cross-check needs for UAS data/research with test data stored in the system.
    b. UAS operational capabilities.
    c. FAA research domains.
    d. FAA functional areas.
    e. Other UAS integration milestones
3. Have the following high-level characteristics:
    a. Leverage best practices currently used among the UAS Test Sites (data collection and categorization/classification).
    b. Provide solutions for potential proprietary issues related to data collection.

   c. Conform with FAA rules regarding software applications (e.g., documentation).
   d. Enable efficient data entry through utilization of the process developed through this effort.
4. Include the features:
   a. Keyword searchable in an interactive manner.
   b. Data mining.
   c. Data tagging.
   d. User friendly.
   e. Intuitive user interface.
   f. Ability to link to supporting reports.
   g. Have a standardized supporting project report template(s).
   h. Ability to incorporate preexisting data.
   i. Ability to export data into multiple formats (i.e., excel spreadsheets, CSV, comma delimited.
   j. Ability to indicate whether test data stored in the system meets a research need or whether additional data/testing would be required.
   k. Adaptability, expandability, and modifiability: It will have the ability to adapt as needs change and gaps are identified.

FAA Research Requirement: Integrating Expanded and Non-Segregated UAS Operations into the NAS: Impact on Traffic Trends and Safety **(A21)**.

UAS Research Focus Area: Operational Safety & Forecasting

This research will provide further insight into the safe integration of sUAS through forecasting of expanded and non-segregated sUAS operations and subsequently collecting data to inform the FAA on risk-based methodologies to safety rules, regulations and revised Safety Management System (SMS) protocols based on forecasted UAS operational needs and performance characteristics. The proposed research, by its design, supports two critical components of the UAS Integration Research Plan: (1) Expanded Operations and (2) Non-Segregated Operations. Expanded operations over people and non-segregated BVLOS operations are anticipated to enable future UAS interoperability in controlled airspace with manned aircraft at varying altitudes and under instrument flight rules. Under this premise, UAS must be properly equipped with technologies that harmoniously exchange data and flight information. This research will serve to examine the avionics equipage and procedures requirements for establishing UAS interoperability with manned aircraft in controlled airspace and stand as a pillar to the FAA's phased integration approach by developing a quantitative framework for risk-based decision making and waiver approvals to meet the growing operational needs and technological evolution of UAS.

Using data and knowledge from on-going integration activities such as the UAS Integration Pilot Program (IPP), Low Altitude Authorization and Notification Capability (LAANC), UAS Traffic Management (UTM), UAS Facility Maps (UASFM), Certificate of Authorizations (COA)/COA Application Process (CAPS), and Special Government Interest (SGI), the research is intended to:

- Understand the emerging usage patterns and missions leading to expanded operations.

- Scope out operations and characteristics of non-segregated operations and potential traffic patterns.
- Understand and describe likely conflict and safety risks.
- Describe risk profile in busy terminal areas and in lower altitudes elsewhere.
- Describe need for safety and certification regulations emanating from integrations.
- Underscore the revisions of SMS incorporating emerging needs of expanded and non-segregated operations.

Successful completion of this research is likely to shed important insights into interactions between human factors, technology, procedures, and further (de)regulations pertinent to UAS integration into the NAS.

FAA Research Requirement: Validation of Low-Altitude Detect and Avoid Standards – Safety Research Facility **(A23)**.

FAA Research Focus Area: UAS Detect and Avoid

The tasking for this work validates prior research in the performance of human pilots to detect other air traffic, assesses the potential for conflict, and analyzes potential maneuver options for avoidance against an intruder aircraft when a potential conflict exists. The results of data and analyses conducted during this effort will be used by the FAA to support a determination of whether the risk ratio safety performance thresholds defined in the ASTM Detect and Avoid standard are adequately safe by comparing them to the measured ability for onboard pilots flying at lower altitudes to see-and-avoid other aircraft.

The Unmanned Aircraft Systems Safety Research Facility's (UASSRF)'s work will be used exclusively by the FAA to determine adequate safety performance thresholds required by DAA Systems that serve as an alternate means of compliance to existing manned aviation see-and-avoid regulations listed in 14 CFR Part 91.113. This work will provide the FAA with information necessary to develop and validate certification standards for DAA systems. This work will be used to develop preliminary, internal, FAA documents to support standards development, policy decisions, and/or rulemaking. See-and-avoid performance metrics are needed that measure the ability of manned aircraft pilots to see and to then avoid conflicts with other aircraft. Different see-and-avoid performance metrics exist depending on whether the pilot uses assistive technologies that aid in visual detection and whether the separation goal being evaluated is to remain well clear of other aircraft or to avoid a near mid-air collision with other aircraft. The results of these assessments are expressed as see and-avoid risk ratios and are intended to inform the establishment of DAA risk ratios for unmanned systems that serve as an alternate means of compliance to see-and-avoid regulations used in manned aviation.

The establishment of safe DAA risk ratio values involve comparing the risk of low altitude UAS operations to the existing risk of low altitude manned aviation operations. This risk comparison necessitates measuring the ability of manned aircraft to see-and-avoid other air traffic.

FAA Research Requirement: UAS Safety Case Development, Process Improvement, and Data Collection **(A24)**.

UAS Research Focus Area: Low Altitude Operations Safety

This research is a follow-on to the UAS Test Data Collection and Analysis (A19) project. In this research, the test data collection and analysis system developed in A19 is exercised to determine how the system can be optimally utilized. The questions about the optimization of the system include:

- Who is best suited to be an applicant for a waiver or exemption and why? Should it be the UAS manufacturer or the individual using the UAS? It could be either depending on the applicant.
- How can prior testing on a vehicle which led to successful waiver/exemption be used in future applications?
- Can an applicant with a full review of a previously successful waiver, use that information for their application?
- Can prior testing on a vehicle which led to successful waiver/exemption be used or referenced by an applicant without any visibility or review by the applicant? (Note: The consideration is towards vehicle test and does not enable an applicant from bypassing the development of their operational procedures, and risk analysis for their specific operations.)
- Should the FAA develop a list and publish the list of approved vehicles for waiver/exemptions? If yes, what additional requirements should the applicant have, i.e., operating procedures, maintenance procedures, etc.?
- Could an applicant cite another waiver's tests without seeing or reviewing the data? Could an applicant buy an off the shelf drone and apply for a waiver without seeing the test results?
- How can safety cases for part 107 waivers be improved?

FAA Research Requirement: Develop Risk-Based Training and Standards for Waiver Review and Issuance **(A25)**.

FAA Research Focus Area: Low-Altitude Operations Safety

The purpose of this research is to provide tools and insight to the FAA to: (1) assist in the development of a more standardized reviewing process for part 107 waivers, and (2) address challenges faced by FAA reviewers when evaluating part 107 waivers using non-standard risk assessment methodologies. This is accomplished by (1) suggesting modifications to FAA orders 8040.4B, “Safety Risk Management Policy” (2017) and 8040.6, “Unmanned Aircraft Systems Safety Risk Management Policy” (2019) (2) developing a framework to modify existing part 107 waiver process and enabling harmonization with alternative risk assessment methodologies (e.g., ASTM and JARUS SORA), and (3) validating the proposed framework through test cases. It is expected that the results of this research will provide guidance and a framework for FAA to review part 107 waivers in a consistent manner that preserves the safety of the NAS. This will ultimately benefit both the FAA and applicants, providing a more straightforward and objective process for waiver review and enable the FAA to provide additional guidance to applicants to ensure that sufficient information is provided in waiver submissions.

This research is intended to:

- Provide recommendations to the FAA on modification to 8040.4B and 8040.6 to incorporate a range of UAS operations.
- Take existing standards (ASTM and JARUS SORA) into consideration, develop a framework to assess various risk components to "feed into" revised UAS-specific tables in 8040.4B and 8040.6. This framework will help waiver proponents articulate the CONOP-dependent safety case for a range of waivered operations. This will, in turn, simplify the burden placed on FAA Flight Standards in determining risk acceptance of proposed operations and simplify the process to establish precedence for a range of UAS operations.
- Validate the proposed modification to 8040.4B, 8040.6, and risk assessment framework by submitting a range of waivers using this proposed system.

Successful completion of this research will provide the following benefits:

- Findings, recommendations, and lessons learned will create transparency between waiver proponents and FAA Flight Standards to streamline the Part 107 Certificate of Waiver process.
- Recommended standards proposed through this research will enable waiver evaluators to utilize a standardized approach for reviewing waivers.
- A standardized methodology for waiver review and issuance enables a precedent-based system in which the FAA reviews waivers consistently and objectively.

The added guidance for FAA waiver evaluators creates a more robust system for processing waivers that ensure consistent outcomes while maintaining safety. In addition, this guidance will assist in addressing issues of compatibility between alternative risk assessment methodologies, FAA Order 8040.4B, and 8040.6.

This research seeks to answer the following questions:

4. How can a modified 8040.4B and 8040.6 enhance the part 107 waiver review process?
5. Can existing industry standards (ASTM, JARUS SORA) inform a framework for proponents to articulate the risk components necessary for the FAA to consider part 107 waivers?
6. What are the minimum requirements for a framework for a risk-based standard for reviewing part 107 waivers?
7. How does a risk-based standard for reviewing part 107 waivers fit into the current waiver review process?

FAA Research Requirement: Establish Risk-based Thresholds for Approvals Needed to Certify UAS for Safe Operation **(A27)**.

FAA Research Focus Area: Operational Safety & Forecasting

This project will validate sUAS industry standards and support standards development and certification strategies for sUAS, necessary for their safe integration in the NAS. As part of the rulemaking effort surrounding the implementation of part 107, the FAA selected ASTM to establish a set of standards for airworthiness, maintenance, and operation in support of part 107. This project will identify weaknesses to make the standards more robust and increase the safety of sUAS operations in the NAS.

The primary tasks within this effort are:

1. Identify limitations associated with the current evaluation paradigm regarding sUAS pilot certification (14 CFR part 107) and report on the potential gaps towards expanded and non-segregated operations.
2. Develop a framework to capture the knowledge, skills, and abilities (KSAs) required for UAS pilots as they relate to classification and category of UAS.
3. Evaluate whether prerequisite levels of manned flight if any, should vary across the classification and category of UAS (i.e., group 2, 3, 4, 5) for expanded and non-segregated operations.
4. Evaluate to determine the constructs associated with pilot training requirements under the auspices of 14 CFR Parts 61 and 141 to determine the transfer of KSAs from manned to unmanned flight in complex UAS operations.
5. Establish a framework to adopt, adapt and exercise current regulatory requirements i.e., Parts 23, 25, 27, 29, 31, 33, and 35) towards performance-based type certification for sUAS (e.g., eBee X, Penguin C, FVR-90, or a similar unmanned aircraft) and a waiver to operate over people within visual line of sight as prescribed in 14 CFR part 107.31.
6. Expand the conceptualized framework to further exercise regulatory requirements associated with performance-based airworthiness criteria to achieve a consistent means of compliance.

FAA Research Requirement: Safety Risks and Mitigations for UAS Operations on and Around Airports **(A31)**.

FAA Research Focus Area: Risks around Airports

The research is intended to address gaps in knowledge that are currently a barrier to the safe, efficient, and timely integrations of UAS into the NAS. This safety and risk analysis will focus on evaluation of UAS operations on and around the airport surface. The research will identify the potential risks with regards to UAS operations on the ground at airports, near manned aircraft, communication with these UAS operators (if necessary), and Air Traffic (AT) services (if not provided). The research may inform potential changes to FAA regulations (such as 7110.65), industrial standards, and best practices.

The proposed research is intended to answer the following research questions and any related questions that may be developed through the research process:

- What are the representative use cases for UAS on and around airport surfaces?

- What level of communication/coordination is required between UAS operators, manned aircraft operators, airport managers, ATC, and other airport users/operators prior to and during UAS operations on and around airport surfaces?
- How do the varying size and capability of different UAS types impact these use cases? For example: 1) Do large UAS traversing the runway/taxiway surfaces require different AT services than smaller UAS? 2) How does UAS size impact the potential integration with or segregation of UAS operations from manned aircraft operations? and 3) How does the size of the UAS change how wake turbulence impacts its behavior?
- What are the impacts of different airspace classes and towered/non-towered airports on these use cases?
- What are the common risks for these representative use cases? What are the unique airspace-class/UAS-specific risks for each use case?
- What are the potential mitigations to identified risks to ensure safe operations for UAS?
- What airport infrastructure would assist in mitigating the hazards of operating UAS on and around airport surfaces?
- What airport policies and procedures would assist in mitigating the hazards of operating UAS on and around airport surfaces?
- How does FAA Order JO 7110.65 (ATC services are not provided to any UAS operating in the NAS at or below 500 ft AGL) impact the use cases and limit potential hazard mitigations for operations on and around airport surfaces?
- What issues identified during the application of the FAA's ATO SMS and SRM processes to the selected use cases should be used to inform potential changes to FAA regulations and industry standards?
- What lessons were learned from these representative use case demonstrations?
- What recommendations from the literature review, use case analysis, SRM process, and flight testing should be highlighted to inform airport operations and design when integrating UAS on and around airport surfaces?

FAA Research Requirement: Urban Air Mobility: Safety Standards, Aircraft Certification and Impact on Market Feasibility and Growth Potentials **(A36)**.

FAA Research Focus Area: Safety Standards Aircraft Certification

In its core proposition and approach, the proposed research is "basic and early-stage applied research" in understanding UAM operations in the NAS. Designed as a short-term research project, the basic results will likely yield effective and "quantitative metrics" in evaluating UAM [Secy. Mulvaney memo, August 17, 2017], as a farther step towards UAS integration into the NAS. Understanding the volume and magnitude of UAM is essential in understanding safety implications and in prioritizing the FAA resources together with timing of allocating these scarce resources. Thus, the proposed research is designed to capture the following characteristics of the market potentials together with the implications on resources:

- Potential size and growth of the market at the local and/or at national level.

- Economic feasibility including price points at which individual market becomes viable.
- Anticipated cost to enter the market, considering factors such as vehicle acquisition and life cycle, operation liability, maintenance and replacement and upgrade schedules.
- Customer segments (e.g., regular business commuters, ad hoc travelers, etc.) for UAM viability.
- Characteristics of population density, traffic patterns including congestions, affordability, and preferred locations.
- Competition for UAM transportation or services (e.g., driverless cars and multi-modal transportation options, on-demand ride hailing services, virtual presence, etc.), providing cost comparisons where applicable.
- Ground infrastructure requirements, legal and management strategies consistent with the envisioned UAM network and connectivity to other transportation modalities as needed for efficient, "door-to-door" travel, and unplanned landing sites.

Furthermore, as part of the part 107 rulemaking effort, the FAA selected ASTM to establish a set of standards for airworthiness, maintenance, and operation in support of part 107. Understanding safety requirements for UAM, drawing upon the lessons learned from part 107, will require understanding barriers for additional demands on the NAS. While some of the existing constraints have been documented [see Thipphavong, et. al. (2018)], detailed analyses are presently unavailable and implications on UAM emergence and its penetration are not clear. For example, it is not evident how UAM:

- May impose demand on additional ATC infrastructure including airspace and workload on controllers?
- May require new paradigm to integrate with UTM and/or ATM?
- May impose demand on regulatory requirements including standards for airworthiness, certifications for design, maintenance and operations for vehicle-level and system-level safety and security?
- Will be resilient to a wide range of disruptions including weather and localized sub-system failures such as GPS?
- Will economically scale to high-demand operations with minimal fixed costs? and
- Will support user flexibility and decision-making including demands emanating from emerging UTM?

This research will identify weaknesses and develop a framework to make the standards more robust and increase the safety of potential UAM operations in the NAS. The projected benefits of this research include:

- Comprehensive analysis of market, feasibility, and projections of future demand together with their locations and timeline.
- Findings, recommendations, and lessons learned will the FAA understanding of Urban Air Mobility certification requirements.

This research also will explore:

- The role of autonomy in UAM vehicles.
- Air traffic management needs via UTM and/or ATM.

Future Research (ASSURE)

FAA Research Requirement: Investigate and Identify the Key Differences Between Commercial Air Carrier Operations and Unmanned Transport Operations **(A41)**.

FAA Research Focus Area: Unmanned Aircraft (UA) Crew Training and Certification, including pilots.

The passenger transportation network ecosystem and its associated technologies are likely to be among the most complex aviation has ever seen and the opportunities to facilitate the full integration of UAS into the NAS are significant. This research aims to characterize this ecosystem and analyze the differences between traditional manned and potential unmanned air transportation. These analyses along with timelines developed as a part of this research will enhance decision making and highlight the anticipated needs of the FAA to support further integration of UAS in air transportation operations in and across metropolitan areas including suburbs and exurbs.

This research seeks to answer the following questions:

- What is the potential for large UAS in carrying passengers in the US? Starting from road transportation and existing air transportation, it is expected that a potential market scope will be laid out.
- What are the likely locations of large UAS to meet demand and growth of air transportation over a period of 10 years?
- Will this change significantly follow the recovery from COVID-19?
- What interface characteristics are necessary for UAS passenger (e.g., UAM) to maintain awareness of aircraft system state with automated aircraft system and subsystem control?
- What are the envisioned characteristics of transition from piloted UAS to fully autonomous UAS in carrying passengers? What are the likely conditions that enable piloted UAS to transition into fully automated UAS and likely timeline?
- What interface characteristics are necessary for the UAS pilot to manage the aircraft's flight path with automated navigation?
- How can the autonomous systems be evaluated or certified such that safe integration of UAS in the existing ATM environment or emerging UTM is enabled?
- How will the UTM paradigm integrate with the large UAS environment? Or will a separate paradigm be needed? How these paradigms will be integrated with the NAS ATM that is already in place?
- How will strategic scheduling of large UAS occur?
- How will the non-scheduled large UAS be handled?

- What other resources and NAS investment may be necessary to facilitate growth of UAS in air passengers?
- What will be the aggregated economic benefits, i.e., direct, indirect, and induced, of integrating large UAS in transporting passengers on the overall economy?

To address these issues, an approach to predicting the larger (>55lb) commercial aircraft growth into the higher non-segregated altitudes (e.g., above 400ft AGL) is needed, with special emphasis on the use of these UAS in transportation of passengers. The approach (i.e., modeling and simulation of airspaces) along with near-term forecast is necessary to understand and prioritize NAS resources as these newer aircraft evolve in serving greater civilian and commercial needs such as air transportation. Finally, this research will inform future regulatory updates to UAS right-of-way rules, DAA performance standards, and collision avoidance standards.

FAA Research Requirement: From Manned Cargo to UAS Cargo Operations: Future Trends, Performance, Reliability, and Safety Characteristics Towards Integrations into the NAS **(A42)**.

FAA Research Focus Area: Unmanned Aircraft (UA) Crew Training and Certification including pilots.

This research is intended to address gaps in knowledge that are currently a barrier to the safe, efficient, and timely integration of UAS into the NAS. This includes the barriers to operating large UAS likely to be transporting cargo by air. This research will develop a framework for understanding and evaluating UAS commercial feasibility together with projected locational (i.e., specific areas) demand. Furthermore, an analytical framework detailing large UAS certification and explore the impact of autonomy on UAS with an emphasis on the cargo environment will be offered as well. Overall, this research has these projected benefits:

- Comprehensive analysis of market, feasibility, and projections of future demand together with their locations and likely network.
- Explicit accounting of effect of COVID-19 on likely adoption trends.
- Findings, recommendations, and lessons learned that will enhance the FAA understanding of Large UAS certification requirements beyond what is available.
- An exploration of the role of autonomy in UAS vehicles beginning with less risky areas (e.g., rural to exurbs) and then onto more populated areas of suburban and metro areas.

Thus, the proposed research is designed to capture the following characteristics of the market potentials together with the implications on resources:

- Potential size and growth of the air cargo market at the local and at national level.
- Economic feasibility including price points and competitive alternative (e.g., traditional delivery by trucks; existing manned air cargo) at which individual market becomes viable.
- Effect of pandemics, such as COVID-19, on the adoption of larger UAS in cargo carrying operations.

- Anticipated cost to enter the market, considering factors such as vehicle acquisition and life cycle, operation liability, maintenance and replacement and upgrade schedules.
- Customer segments (e.g., warehouses, business locations, residential nodes, etc.) for UAS viability in air cargo.
- Characteristics of population density, traffic patterns including radius of feasible logistics, affordability, and preferred locations for cargo hubs (i.e., defined network) vis-à-vis point-to-point deliveries (i.e., open delivery network).
- Characteristics of resulting network: defined network (i.e., delivery between defined end points such as warehouse to homes) vs. open delivery network (i.e., delivery to any location).
- Competition for UAS transportation or services (e.g., cargo hauling by road transportation, traditional air cargo modes etc.), providing cost comparisons where applicable.
- Ground infrastructure requirements, legal and management strategies consistent with the envisioned UAS network for air cargo and connectivity to other transportation modalities as needed for efficient, "door-to-door" supplies, "door-to-cargo hubs," and planned or unplanned landing sites.
- Direct and indirect economic benefits of integrating large UAS in air transport and induced economic benefits of this transformation.

FAA Research Requirement: Mitigating GPS and ADS-B risks for UAS **(A44)**.

FAA Research Focus Area: Detect and Avoid.

Unvalidated or unavailable GPS and “ADS-B In” data poses security and safety risks to automated UAS navigation and to Detect and Avoid operations. Erroneous, spoofed, jammed, or drop-outs of GPS data may result in unmanned aircraft position and navigation being incorrect. This may result in a fly away beyond radio control, flight into infrastructure, or flight into controlled airspace. Erroneous, spoofed, jammed, or drop-outs of “ADSB-In” data may result in automated unmanned aircraft being unable to detect and avoid other aircraft or result in detecting and avoiding illusionary aircraft. For automated Detect and Avoid, a false ADS-B track can potentially be used to corral the unmanned aircraft to fly towards controlled airspace, structures, terrain, and so on. This research is necessary to enable safe and secure automated sUAS navigation and safe and secure automated sUAS Detect and Avoid operations. Goals for the project include reports and recommendations useful for FAA policy development and UAS standards development. It is expected that this information will be used to better understand the risks, potential mitigations, and help the FAA to reassess and refine FAA policy with respect to validation of ADS-B data. The research may lead to new navigation requirements related to GPS as well.

The research requirement is intended to assess the safety and security risks of unvalidated GPS and ADS-B In data used to support a variety of UAS operations to include sUAS operations, unmanned cargo transport, and remotely piloted passenger transport operations. For sUAS operations, particular emphasis will be on low cost and easy to implement mitigations commensurate with their safety and security risks. The research will address the following research questions and any related questions that are developed through the research process:

- What are the potential security and safety risks associated with reliance on GPS and

ADS- B In data for different categories of UAS operations to include: sUAS operations, unmanned cargo transport, and remotely piloted passenger transport operations?
- Are there effective, low cost, and easy to implement solutions to mitigate GPS and ADS- B risks for sUAS operations?
- What potential solutions exist for unmanned cargo transport and remotely piloted passenger transport operations?
- What policy recommendations should the FAA consider to better manage potential security and safety risks associated with reliance on GPS and ADS-B data for different categories of UAS and their operations?

FAA Research Requirement: Shielded UAS Operations: Detect and Avoid **(A45)**.

FAA Research Focus Area: Detect and Avoid.

Certain sUAS BVLOS operations, such as structural inspection, may be in close proximity to structures that are collision hazards for manned aircraft. These types of operations that are in close proximity to manned aviation flight obstacles such that they provide significant protection from conflicts and collisions with manned aircraft are termed “shielded” operations. Industry and the FAA believe that some reduction in DAA requirements (to avoid other aircraft) when shielded by flight obstacles may be appropriate. Currently there is no comprehensive analysis to determine the correct balance between mitigating UAS hazards with other nearby low altitude manned aircraft and enabling shielded operations. This work effort is intended to identify risks and recommend solutions to the FAA that enable shielded UAS operations. This effort will identify risks, determine whether shielded operations can be made safe, to what degree UAS Detect and Avoid requirements can be reduced, and recommend UAS standoff distances from manned aviation flight obstacles.

This project is intended to inform rulemaking and has applicability to BVLOS operations, DAA, and right-of-way rules. This effort is also intended to support the next phase of the ASTM DAA standard that is expected to include DAA shielding concepts.

The Massachusetts Institute of Technology Lincoln Laboratory has performed some initial analyses under a UAS Science and Research Panel (SARP) effort that evaluated how close helicopters get to buildings in the Boston area. Internally, the FAA has explored shielding concepts that mitigate conflicts with manned aircraft. These previous efforts will be leveraged to help provide a foundation for this effort.

The effort of this project will focus on the following research questions:
- What types of sUAS failures may increase collision risks when operating near obstacles, structures, and critical infrastructure? What are some recommended mitigations to address these risks? For instance, are obstacle avoidance capabilities needed for shielding operations near critical infrastructure?
- What are safe standoff distances (vertical and horizontal) from obstacles, structures, and critical infrastructure for sUAS BVLOS operations?

- What types of manned aircraft operate in close proximity to flight obstacles and structures? How often do they operate in close proximity? How close do they fly to these structures? What are their operational limitations (day only, special procedures, special pilot requirements, etc.)?
- What other mitigations should be coupled with shielding concepts in order to manage collision risks with manned aircraft and with obstacles?
- To what degree can DAA requirements to avoid other aircraft (manned and unmanned) be reduced during shielded sUAS operations?
- What regulatory, policy, and legal issues should the FAA consider for shielded sUAS operations?
  - Example topics include:
    - What should the FAA consider so as to not be negligent in their risk management responsibilities when issuing waivers involving shielding operations?
    - What are the potential implications if an accident with a manned aircraft occurs, and the FAA waived DAA requirements?
    - What are the potential implications if the FAA does not require active obstacle avoidance capabilities and a collision with critical infrastructure occurs?

FAA Research Requirement: Small UAS (sUAS) Mid-Air Collision (MAC) Likelihood **(A47)**.

FAA Research Focus Area: Low Altitude Safety.

The primary goal of regulating UAS operations in the NAS is to assure an appropriate level of safety. This goal is quantified by national aviation agencies as an “Equivalent Level of Safety” (ELOS) with that of manned aviation. There are major key differences between manned and unmanned aviation that do not only lay in the separation of the pilot from the cockpit and the level of automation introduced but also in the variety of architectures and materials used for the construction of UAS. These differences could introduce new failure modes, and, as a result, and increased perceived risk that needs to be evaluated. In order to have an equivalent level of safety, according to the definition of the Range Commanders Council in its guidance on UAS operations it states that, any UAS operation or test must show a level of risk to human life no greater than that for an operation or test of a piloted aircraft.

The aforementioned metrics provide statistical probabilities of UAS mid-air collisions according to specific parameters defined for the evaluation. It should be noted that not all collisions lead to catastrophic accidents. The large variability of UAS sizes and the fact that not all the aircraft systems are critical for remaining airborne means that the aircraft involved may survive certain collisions.

The risk assessment to develop an Airborne Collision Unmanned Aircraft Systems Impact Severity Classification can be divided into three elements:

- Estimation of the probability of mid-air collision between UAS and manned aircraft. This will be a function of the operating airspace, aircraft operated within the airspace and the UAS configurations operating within the shared airspace.

- Evaluation of damage potential for typical UAS (classes based on weight, architecture, operational characteristics [altitude, velocity] mid-air collisions scenarios per manned aircraft class (commercial, general aviation, rotorcraft...) in order to assess the damage severity to manned aircraft. Several groups advocate to use simplified ballistic penetration models, similarity principles to existing bird strike requirement or kinetic energy thresholds. The objective of this project is to evaluate the severity of a typical quad and fixed wing UAS airborne collision. These results will be compared with current proposed penetration mechanics and energy-based criteria.

- Once the probability of an airborne collision is determined, the damage models can be combined with the probabilistic collision models to define appropriate Equivalent Level of Safety criteria.

To complement other collision severity research and produce a complete risk assessment of sUAS MAC with manned aircraft, MAC likelihood research needs to be completed. Because collision severity depends on where the collision occurred on a manned aircraft, this likelihood research will not only investigate overall MAC probabilities but also the MAC probabilities with different parts of manned aircraft. This likelihood assessment will investigate sUAS collisions with both General Aviation and Commercial aircraft.

The following research questions will guide this project:

- What is the probability of a UAS without a detect and avoid (DAA) system colliding with a manned aircraft?
- What is the probability of a UAS with a detect and avoid system colliding with a manned aircraft?
- What role does altitude play in collision likelihood?
- What is the overall risk of MAC with and without a detect and avoid system?
- How does UAS collision risk compare with the risk of a bird strike?

This research project has the following projected benefits:

- Unmitigated and Mitigated MAC probabilities models will be developed.
- Collision probabilities with individual parts of a manned aircraft will be considered.
- UAS Data from actual, real-world flight operations, will be used; it does not rely on Monte Carlo methods or other assumptive simulations.
- Manned Aircraft flight data is derived from ADS-B sources and provide measured improvements in accuracy and higher sampling rate than radar data.

The FAA's UAS Integration Research Plan contains identified research needs that will spawn additional requirements for ASSURE research. As the full integration of UAS into the NAS becomes closer to reality, the need to set the standards, rules, and regulations governing will require additional, more complex, safety analyses and testing by the ASSURE team in conjunction with industry consensus standards and FAA rulemaking.

ASSURE Relationship to Industry Consensus Standards

One of several avenues to bring the outputs of ASSURE research to industry is through participation in industry consensus groups, such as ASTM International. Participating in such groups provides a mechanism to bring lessons learned through research to industry by informing the development of standards. This approach enables a translation of research outcomes to industry and enables a means to validate findings.

The following past and current ASSURE research projects have involved participation in industry consensus standards groups, ASTM International in particular. While this list in not all-inclusive, it provides a snapshot of some of the contributions that ASSURE research has made to the standards development community. It also highlights some key focus areas where ASSURE has made significant contributions to the body of knowledge, helping to steer industry focus and inform solutions to various challenges facing the UAS industry as a whole.

ASSURE A1: Certification Test Case to Validate sUAS Industry Consensus Standards

This research involved the validation of ASTM standards for use in developing flight test plans for UAS type certification. As part of this research, the team generated a flight test program for as UAS. Outcomes of this research informed revisions to ASTM F2910 as well as the development of F3298 – Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS).

ASSURE A18: Small UAS Detect and Avoid Requirements Necessary for Limited Beyond Visual Line of Sight (BVLOS) Operations

ASSURE A18 addresses testing for small UAS detect and avoid systems for use in beyond visual line of sight (BVLOS) flight. At the time this report was drafted, research for ASSURE A18 is ongoing. The research team for ASSURE A18 has been actively engaged in the development of standards for use in setting performance and testing requirements for detect and avoid (DAA) systems. These standards include:

- ASTM F3442/F3442M – 20: Standard Specification for Detect and Avoid System Performance Requirements
- ASTM WK62669: New Test Method for Detect and Avoid

ASSURE A27: Establish risk-based thresholds for approvals needed to certify UAS for safe operation

Research through ASSURE A27 is ongoing at the time this report was drafted. ASSURE A27 revolves around determining thresholds and processes for risk-based approvals for type certification of UAS, to include requirements for pilot training. A key element of ASSURE A27 research is the participation in the ASTM WK70877 working group: New Practice for Showing Durability and Reliability Means of Compliance for Unmanned Aircraft Systems. This research also involves following an applicant through the type certification process and documenting procedures, challenges, and methodologies to provide additional insight to both the FAA and industry.

Continued engagement with industry consensus bodies is critical to translating ASSURE research to industry. It not only serves to assist regulators in translating research to industry, but it also serves as a means to validate findings. The same is true for the development of a low-altitude risk assessment roadmap. Engagement with industry will be critical in establishing sources of key data points and processes to build upon data categories identified through ASSURE A25 research.

<u>Low-Altitude Risk Assessment Roadmap – Outline</u>

What follows is an outline of the low-altitude risk assessment roadmap that resulted from ASSURE A25 Task 1-3. This roadmap represents a selection of data categories that the ASSURE A25 research team derived through input from subject matter experts (SMEs), ongoing ASSURE research, and knowledge of risk assessment practices and methodologies. As such, it represents the research team's best effort to identify data categories required to characterize low-altitude airspace environments and associated gaps in information. With the apparent need to understand and characterize a vast array of low-altitude operating environments, the research team intends for this roadmap to inform follow-on research to expand these data categories into populated sets of information that can point towards (1) standards and practices for low-altitude risk assessment and (2) policy regarding low-altitude UAS operations.

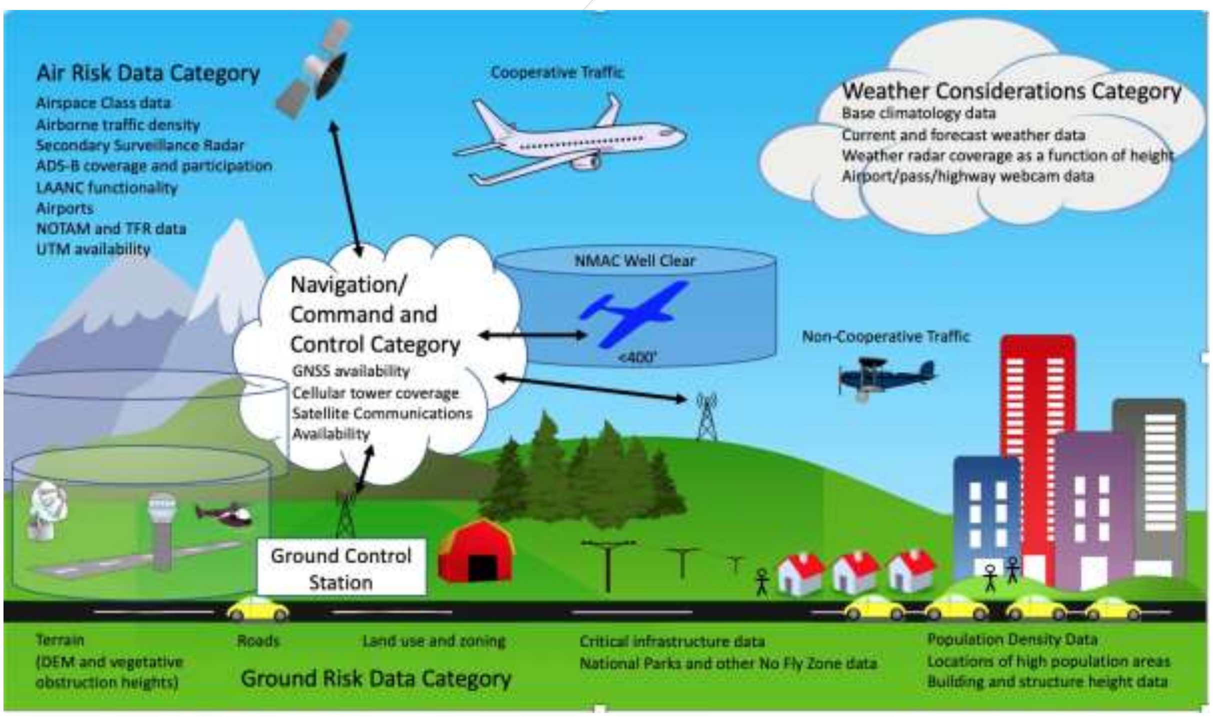

Figure 6. Representation of data categories for low-altitude risk assessment.

1.1. Air Risk Data Categories

Data categories in this section have relevance in determining air risk components required for a low-altitude risk assessment. While this list is not exhaustive, it provides a starting point for variables to consider when developing methodologies for quantifying the level of air risk associated with a given UAS flight operation. As such, data categories and variables highlighted in this section rely heavily on the work performed by the Massachusetts Institute of Technology Lincoln Labs (MIT LL) to develop a series of probabilistic models for airspace encounters – e.g., airspace encounter models. These models were developed using various sources of openly available geospatial information, map data, and aircraft characteristics and rely on extensive use of Monte Carlo simulation to provide probabilistic collision models to cover a large number of encounter scenarios.

Work performed by the MIT LL yielded five sets of encounter models that are useful for providing a starting point for baseline low-altitude air risk. These models, as highlighted in Weinert et al. (2020), are:

1. Uncorrelated Encounter Model – Applicable for non-cooperative aircraft without ATC services

2. Correlated Encounter Model – Applicable for cooperative aircraft with ATC services

3. Encounter Models for Unconventional Aircraft – Applicable for unconventional aircraft without a transponder equipped

4. Due Regard Encounter Model – Applicable for UAS flying in oceanic airspace flying with due regard

5. Helicopter Air Ambulance Model – Applicable for evaluating system performance for helicopter air ambulance encounters.

More detailed descriptions of these encounter models are out of scope for this research. However, detailed descriptions of these encounter models and their baseline assumptions and constraints may be found in Weinert et al. (2020).

While an in-depth assessment of the encounter models is out of scope for this research, the models do include important data categories and variables that are essential for establishing a clear picture of air risk. As such, the data categories that follow rely heavily from literature regarding the development and application of these encounter models.

The models developed by MIT LL are intended to be leveraged by industry and standards bodies to develop DAA performance standards and to show that an applicant's system is compliant with those standards by having adequate DAA performance.

1.2. Airspace Class

The different national airspace classes can be grouped into controlled and uncontrolled airspaces. For small UAS under part 107, the primary airspace available is uncontrolled airspace (class G) below 400 ft AGL. This does not mean, however, that all this volume of airspace is available to small UAS operators. This data category supports the identification of risks associated with an inadvertent incursion into prohibited areas. Flight plans should be checked against data sources indicating the airspace class. Airspace features and aviation infrastructure can be accessed through the National Airspace Resources (NASR) database (FAA, 2020k). Every risk of incursion into unauthorized areas should be properly mitigated. However, the information in this data category should be complemented with other data categories, such as “Zoning” or “National Parks and other no-fly zones.” The following figure illustrates where a UAS is allowed to fly, and where it needs ATC authorization and/or waiver.

Figure 7. Airspace Guidance for sUAS Operators.

1.3. Airborne Traffic

This category also includes traffic type, speed, and trajectory information. Traffic type is broken down into manned/unmanned, and cooperative/non-cooperative traffic. Airborne traffic data is important for UAS flight planning because it can provide operators with insight into the best routes and times to fly to limit the potential for encounters with traditional aircraft. It can also help a UAS operator choose the best DAA technology for their operation by determining if everyone is cooperating and transmitting their locations so an ADS-B in DAA solution would be helpful or if there is a large component of non-cooperative traffic that might require an onboard radar DAA solution to detect.

MITRE (2017) identifies the UAS Accidents Report Database, owned by the FAA, as an information source related to this data category. The data years range between 2010 and 2014 when 105 occurrences were reported. The following information is downloadable at FAA (n.d.): Sponsor category, Sponsor, Event Date, Event Location, Event Type, and Aircraft Type. However, the reports themselves are not publicly available.

Alternatively, some of the following sources could provide more information:

- NTSB Aviation Accident and Incident Database (NTSB, n.d.).
- FAA Aviation Safety Reporting System NASA, (FAA, n.d.a).
- SkyWatch is a data source owned and managed by the FAA, with restricted access. (FAA, n.d.b).
- UAS Sightings reported to the FAA since November 2014 can also be accessed at FAA (2020g).
- Finally, the Near Mid-Air Collision System (NMACS) allows textual search across a wide range of data fields and is available at FAA (n.d.c).

MITRE’s Centre for Advanced Aviation System Development (CAASD) has been developing Threaded Track since 2011. It consists of a compilation of several surveillance sources into a synthetic trajectory (Ahmed et al., 2017). Each of these data sources (which are radar-based) has different coverage and quality aspects associated, which may be considered during the integration process. Position reports from Terminal Radar Approach Control (TRACON) facilities, Air Route Traffic Control Centers (ARTCC) Airport Surface Detection Equipment, model X (ASDE-X), Enhanced Traffic Management System (ETMS), and Automatic Dependent Surveillance (ADS-B) are combined using the callsign as a unique identifier for each flight, thus avoiding ghost flights and data duplication. Unassociated data (flights not associated with a specific callsign) are also included in Threaded Track. This last group is made of VFR and General Aviation (GA) traffic, IFR over-flights, and redundant coverage, and noise. Radar information in ARTCCs and TRACONs is obtained through the National Offload Program (NOP) that the FAA established in 2010. The information is complemented with ETMS from the same Common Message Set (CMS) data provided by the NOP as provided by ARTCC. Threaded Track data is archived in MITRE’s Center for Advanced Aviation System Development (CAASD) with FAA Air Traffic Organization’s (ATO) permission. They are only accessible by MITRE staff working on FAA projects.

FAA also owns the Performance Data Analysis and Reporting System (PDARS). PDARS is a specialized software to collect ATM data from the NAS. It is available in 20 ARTCCs (En-Route Automation Modernization, ERAM data), 28 TRACONS (through the Automated Radar Terminal System, ARTS and Standard Terminal Automation Replacement System, STARS), and airports (35 ASDE-X sources). It is intended for government use only. PDARS shares with Threaded Track compatibility issues among sources used. PDARS is only for government use, and commercial and academic exploitation is prohibited.

Finally, radar data from the 84th Radar Evaluation Squadron (RADES) located at Hill AFB, UT provide information on VFR flights (A-coded 1200). RADES receives radar data from FAA and DoD sites. They maintain continuous real-time feeds from a network of sensors with radar ranges spanning from 60 to 250 NM. Weinert et al. used 229 VFR reports from 84 RADES in 2013 to develop a model for aircraft close encounters, in which at least one of the aircraft is under VFR rules (Weinert et al., 2013).

1.4. Secondary Surveillance Radar

The 84th Radar Evaluation Squadron (RADES) monitors, evaluates, optimizes, and integrates fixed and mobile long-range radars for both the operational and federal communities. RADES capabilities include:

- Performance monitoring (480 sensors from the four military sectors),
- Sensor evaluation/optimization (211 sensors), and
- Radar obstruction evaluation (OE): Evaluation of radar impact caused by various obstructions (building constructions, wind turbine, etc.)

The data is forwarded to the North American Aerospace Defense Command (NORAD) and Air Combat Command (ACC) HQ.

1.5. ADS-B Coverage and Participation

The FAA currently maintains an interactive map that can be displayed in Google Earth, which highlights ADS-B coverage at various altitudes, equipage requirements for various spaces classes, and radar coverage. Challenges related to uncertainties on the temporal resolution of this data set make it unsuitable for navigation and flight planning. However, this tool is useful to identify areas where ADS-B coverage may not be guaranteed, and it provides a starting point to identify airspace volumes where ADS-B equipage and usage may become an important factor in a low-altitude risk assessment. A link to the FAA's Google Earth ADS-B plugin is downloadable at FAA (2020a).

OpenSky collects worldwide data via a network of crowdsource ADS-B receivers. The network began operations in 2012 using 12 European sensors, but since then, it has grown to over a thousand of them distributed around the globe. In the U.S., ADS-B equipped aircraft use Mode-S (the ICAO standard), or Universal Access Transceiver (UAT) links to automatically self-report their position to ground stations and other equipped aircraft.

In order to analyze ADS-B participation in low altitude operations, one must consider ADS-B coverage. Fewer ADS-B communication messages below 400 ft than above do not mean less ADS-B messaging in that portion of airspace, but its use might be impaired by VLOS obstructions.

1.6. LAANC Functionality

The FAA UAS Data Exchange is a collaborative approach between government and private industry facilitating the sharing of airspace data between the two parties. Under the FAA UAS Data Exchange umbrella, the agency will support multiple partnerships, the first of which is the Low Altitude Authorization and Notification Capability (LAANC). As of September 2020, 726 airports and 537 air traffic facilities participate in LAANC (FAA, 2020j).

LAANC offers the following information:

- Awareness of where pilots can and cannot fly.
- Air Traffic Professionals with visibility into where and when UAS are operating. It is noteworthy the remark of certain sources on the fact that some manned aviators do not have visibility on UAS operations (Aviators Code Initiative, 2019).

1.7. Airports

FAA definition of airport is: "[An] area on land or water intended to be used either wholly or in part for the arrival; departure and surface movement of aircraft/helicopters." FAA airports information can be found at FAA (2020k).

1.8. NOTAM and TFR

Notice to Airmen (NOTAMs) and Temporary Flight Restrictions (TFR) can be accessed through FAA (2020d).

1.9. UTM Availability

Unmanned Aircraft System Traffic Management (UTM) is a separate management system for UAS but complementary to FAA Air Traffic Management (ATM) system. The research team that leads the transition towards full UTM integration into the NAS is composed of NASA, FAA, and industry participants. It aims at identifying airspace operations requirements for visual line of sight (VLOS) and beyond visual line of sight (BVLOS) operations for UAS. NASA and FAA have jointly collaborated in the development of the UTM Research Plan. Recent activity in UTM comprises:

- The second version of the UTM Concept of Operations (CONOPS) was released on March 2, 2020 (FAA, 2020e).
- Technical Capability Level (TCL) 4 was completed in August 2019 with tests in Reno, NV, and Corpus Christi, TX. (NASA, 2020).
- The FAA set up the UTM Pilot Program (UPP) to define a set of capabilities to support UTM operations (FAA, 2020h).

Following the FAA modernization and Reform Act of 2012 and the FAA Extension, Safety and Security Act of 2016, the FAA established seven UAS Test Sites around the country. Their main objective is to "provide verification of the safety of public and civil UAS, [*sic.*] operations, and related navigation procedures before their integration into the NAS." (FAA, 2020f).

The use of UTM is optional and may be limited by infrastructure limitations in specific areas of the United States. The use of UTM does not supplant or lessen the need for DAA in UAS operations. However, in the future, UTM could provide a way to deconflict UAS routes in high density UAS operations areas, share weather data among UAS operators, or provide ground-based surveillance as another facet of a DAA solution.

1.10. Ground Risk Data Categories

Data categories under this label cover population distribution, terrain geography, as well as man-made structures.

1.11. Population Density

An area's current population density is an ideal data point to help understand the risks that an aircraft operation poses to people on the ground. However, short of real-time location monitoring of cell phone location data, there may be large inaccuracies in population density data. Population density varies by time of day, specific days of the year, and scheduled and unplanned events such as concerts and sports. A potential compromise that comes short of real-time location monitoring is using anonymized historical location data from cell phones. This type of data is commercially available through providers like AirSage (AirSage, n.d.). Also, population density data is normally available through local administrations.

In compliance with the Operations of Unmanned Aircraft Systems Over People rule negates the need to determine population density for a UAS operation conducted over people. However, information about the population density of an area can help an operator avoid noise and privacy complaints by planning flights that avoid times when and where people will be present.

1.12. Locations of High Population Areas

The Next Generation 911 system's implantation has improved the quality of Geographic Information System (GIS) data available to dispatchers. This data includes the identification of high-population areas. Although it is decentralized to local dispatch offices, there could be an effort to consolidate information from the Next Generation 911 system relevant to quantifying the risk of aircraft operations to a particular environment. Next Generation 911 GIS data can be supported with different business solutions, one of them being ArcGIS (ArcGIS, n.d.). Public Safety Answering Points (PSAP), designated centers to receive and route 911 calls, are in the process of being upgraded to a digital environment. GIS maps provide road centerlines names and location.

1.13. Terrain (DEMs and Vegetative Obstruction Heights)

The 3D Elevation Program (3DEP) will provide a nation-wide, lidar-based Digital Elevation Model (DEM) by 2021. This program is managed by the U.S. Geological Survey (USGS) National Geospatial Program (USGS, n.d.a). Other DEMs exist, although with less resolution as that offered by 3DEP. These are:

Digital Terrain Elevation Data (DTED) standards DTED2 and DTED1 from the National Geospatial-Intelligence Agency (NGI) with 1-arc second and 3-arc seconds resolution respectively are only available to the Department of Defense (DOD), DOD contractors, and U.S. Government agencies supporting DOD functions. DTED0 shares 30-arc seconds resolution with other models such as GLOBE, GTOPO30, and its enhancement GMTED2010. GLOBE data is available through the National Oceanic and Atmospheric Administration (NOAA) website (National Centers for Environmental Information, n.d.a). Its cost is $25. GTOPO30 is available through EarthExplorer. GMTDE2010 can be visualized in GMTED2010 Viewer (n.d.).

GTOPO30's root mean square error (RMSE) is 66 m, whereas GMTDE2010's ranges between 26 and 30 m.

1.14. Land Use and Zoning

Land use and zoning data are decentralized to local municipalities. There are also some municipalities that are not zoned. Therefore, the data quality can vary, and it would take an extensive consolidation effort to integrate this data.

1.15. Building & Structure Heights

Building and structure heights are another decentralized data category. One location where this data is found is in local airport master plans. Although this data source would not cover all possible building and structure heights, it would provide heights of buildings and structures close to airports infrastructures. Another potential data source is the FAA's Digital Obstacle File, which is updated every 56 days and can be accessed at the FAA's website (2020c).

1.16. National Parks and Other No-Fly Zones

A data source that can help identify national parks and determine if a property is privately or publicly owned is OnX Hunt app. (OnX 2020). This data source is an application that has been conceived to help hunters identify hunting locations and contact information. The data could be used to help to characterize the risk posed on a protected environment by a UAS operation. Another nation-wide data set that may have applicability to aid the characterization of environmental risk is the Landfire program (n.d.). This program contains publicly available information.

Partnered with the FAA, Kittyhawk has developed the B4UFLY app for UAS users to gather information on safe areas to fly (Kittyhawk, 2020). Examples of areas where operations are restricted include Special Flight Rule Area around Washington D.C., critical infrastructure, airports, military training routes, and temporary flight restrictions. The B4UFLY app is available for free at the App Store for iOS and Google Play Store for Android.

1.17. Critical Infrastructure

There are several open-source databases of geospatial information relating to critical infrastructure that are available for free. While not exhaustive, this section provides a brief list of commonly available information related to power lines, rail lines, roads, and pipelines. These sources were identified by Weinert (2020) for the purpose of defining UAS use cases as inputs for encounter models. Examples of information locating critical infrastructure are shown below:

- Linear infrastructure
  - Power transmission lines: U.S. Department of Homeland Security (DHS) Homeland Infrastructure Foundation Level Data (HIFLD) (Homeland Infrastructure Foundation-Level Data, 2020).

- Railway tracks: Geofabrik OpenStreetMap (OSM) (Geofabrik, 2018). A German product, full metadata is available to Geofabrik OSM contributors only.

- Pipelines: U.S. Energy Information Administration (EIA) provide information on pipelines locations for crude oil, hydrocarbon gas liquids, natural gas, and petroleum products (Energy Information Administration, n.d.). In particular, crude oil pipeline's location can be downloaded directly here: https://www.eia.gov /maps/map_data/CrudeOil_Pipelines_US_EIA.zip

- Roads: There are several sources that provide information on roads. Among others, the Natural Earth data has 10 m accuracy and have been extracted from the CEC North America Environmental Atlas (Natural Earth, 2020).

- Aviation obstacles: The FAA provides information on nearby airports (FAA, 2020b).

These open data sources are publicly available. However, Weinert (2020) notes that, "A challenge is that many datasets do not guarantee complete coverage of all features. This issue exists for both federally managed and open-sourced datasets. The information available across datasets vary too, and correlating datasets can be challenging" (A. Weinert, 2020, p. 11). This implies that while these data sources may be useful, their accuracy may be difficult to determine.

In addition to the sources listed above, the B4UFLY app may also provide additional information relating to critical infrastructure.

1.18. Roads

Road data are decentralized to local municipalities. Although a nation-wide data does exist, it can be limited in scope and quality. It would take an extensive consolidation effort to integrate the higher quality data housed by local communities. For more information, see "Critical Infrastructure" subsection above.

1.19. Navigation/Command and Control

Data categories under this group are related to navigation satellite systems, and communications platforms for command and control (C2), either satellite- or ground-based.

For DAA systems, the FCC will categorize radar as appropriate for either radiolocation or radionavigation. Radiolocation involves an unprotected spectrum where there may be unintended interference. Radiolocation radar may be appropriate for zero-conflict and "safe state" BVLOS operations. Radionavigation radar is the preferred choice when maneuvering around an intruder aircraft. Protected spectrum is not only important for DAA but for C2 systems during BVLOS. FCC licenses on the FCC website will state whether a license falls under radiolocation, radionavigation, or may accept interference (i.e., not protected spectrum).

1.20. GNSS Availability

To date, DoD maintains the Global Positioning System (GPS) without selective availability. The complete GALILEO deployment (24 satellites + 6 active spares) is expected by the end of 2020.

1.21. Satellite Communication Coverage

Two satellite constellations provide services to cell phone companies: Iridium and Globalstar. Iridium NEXT satellites number 66, distributed in six rings (i.e., 11 satellites per ring) located at 485 miles above the Earth. Each satellite has an orbital period of 100 min and travels at a speed of 17,000 mph on average. Iridium satellites add a latency to the system of about 40-50 ms. A coverage map can be found at GroundControl (n.d.).

Globalstar constellation consists of 24 satellites in LEO orbit, distributed in eight orbital planes of six satellites each. With an orbit inclination of 52^{o}, they provide full coverage between 70^{o}N and 70^{o}S. Their orbital period ranges from 114 to 130 min. A coverage map of Globalstar can be found at GlobalCom (2019).

1.22. Cellular Coverage

Several websites provide information on cellular coverage. By introducing a zip code or address, a map can be zoomed in a specific area within the U.S. It is also noteworthy that the U.S. Department of Agriculture (USDA) is currently working on several programs to make broadband connectivity available in rural areas around the country. Cellular coverage data is provided in the form of maps. Depending on the website used, information on different network providers and standards can be retrieved:

- US Cellular (USCellular, n.d.): Coverage on 5G, 4G Long Term Evolution (LTE), 3G Data and 4G LTE roaming.
- T-Mobile (T-Mobile, n.d.a) It provides a comparison between T-Mobile, AT&T and Verizon coverage.
- Verizon (Verizon, 2020): 5G ultra-wideband, 5G nationwide, 4G LTE and 3G coverage.
- AT&T (ATT, n.d.): 5G and 4G LTE coverage.
- Sprint (merged with T-Mobile in 2020) (T-Mobile, n.d.b): 4G LTE coverage.

A compatible device is required to connect to a specific network. The following issues should also be considered when using each of the sources above:

- US Cellular: The map shows an approximation of service coverage. Actual coverage may vary. Service may be interrupted or limited due to weather, terrain, customer equipment, or network limitations. Coverage indoors may also vary. US Cellular does not guarantee coverage.

- T-Mobile: The website does not present any restrictions to the data.

- Verizon: A coverage disclaimer is included. Among other things, they are not a guarantee of coverage, and wireless service subject to network and transmission limitations. Also, customer equipment, weather, topography, and other environmental considerations associated with radio technology also affect service and service may vary significantly within buildings. The accuracy of the data is not guaranteed.

- Sprint: A disclaimer is presented with similar aspects highlighted in US Cellular or Verizon.

1.23. Weather Considerations

A broad spectrum of weather information tools exists. Only some of them are aviation specific. For those that are not, the National Oceanic and Atmospheric Administration (NOAA) provides a good starting point of weather data information, although the industry has also developed useful tools for weather assessment.

1.24. Base Climatology

The National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information provide a broad range of historical weather products. Temperature and precipitation values, and weather anomalies can be retrieved with different granularity (daily, monthly, seasonal, and annual), for the CONUS and Alaska. This data can be retrieved from NOAA (National Centers for Environmental Information, n.d.b).

1.25. Current Conditions

UAS operators should consider the accessibility to and use of sources for weather current conditions in their area, previous to the intended flight. Meteorological Aerodrome Reports (METAR) are the international standard code format to provide weather information at airports. Information included in METARs reports include current wind direction and speed, visibility, cloud cover, temperature, and dewpoint. However, METARs are limited to geographical regions at or on airport surroundings. They are updated hourly, unless significant weather changes occur, in which case the frequency is adapted to the specific phenomenon. In this last case, the report is called SPECI. METAR data can be retrieved from the Aviation Weather Center (n.d.a).

1.26. Forecast Conditions

As with current weather conditions, UAS operators should consider the accessibility and use of sources for weather forecast conditions in their area, previous to operations. Terminal Area Forecast (TAF) are the international standard code format to provide weather forecast at terminal areas (5 miles from the Airport Reference Point, ARP). On a broader range, the NOAA also has a broad range of forecast products.

TAF uses the same descriptors as METAR. NOAA uses two information ranges, short range (up to 48 hr) and medium range (up to six days) forecasts for pressure patterns, circulation centers, and fronts. Maps on temperature, dewpoint, sky cover and amount of precipitation are also available. TAF reports are valid for 24 hr. and are updated every six hours. NOAA maps provide a forecast for every 3hr. range. TAF data can be retrieved at Aviation Weather Center (n.d.b).

A broad set of weather graphical information can be retrieved at the National Oceanic and Atmospheric Administration (n.d.a).

1.27. Weather Radar Coverage as a Function of Height

NOAA uses the Next Generation Weather Radar (NEXRAD) and the Terminal Doppler Weather Radar (TDWR) to obtain precipitation and wind information in a given area. NEXRAD is a network composed of 159 radars which uses S-band doppler technology. It is managed by NOAA, the FAA, and the U.S. Air Force. TDWR is a radar network operated by the FAA which is used primarily for the detection of hazardous wind shear conditions, precipitation, and winds aloft on and near major airports situated in climates with great exposure to thunderstorms in the United States. Data coverage products come in a map form. NEXRAD and TDWR coverage is available for 3,000 ft, 6,000 ft, and 10,000 ft AGL (National Oceanic and Atmospheric Administration, n.d.b).

1.28. Airport/Pass/Highway Webcams

Helios® is an image-based, real-time system operated by L3Harris, which feeds on a network of thousands of public and private sensors and apply built-in analytics from which to extract information. Weather validation can assist go-no-go decisions (L3Harris, 2020). A potential data source to validate localized real-time, Helios uses machine vision to automatically categorize the weather, particularly precipitation, based on public and private video cameras. Weather validation can assist go/no-go decisions as well as inform the weather context after an operation. Helios® access requests are submitted through their website (L3Harris, n.d.).

1.29. Morning and Evening (Civil Twilight Times as a Function of Time of Year)

Sunrise and sunset times updated every day for most locations around the country. Information provided also includes civil twilight (when the geometric center of the Sun's disk is between 0^{o} and 6^{o} below the horizon), nautical twilight (6^{o}-12^{o}) and astronomical twilight (12^{o}-18^{o}). Both dawn and dusk times are available.

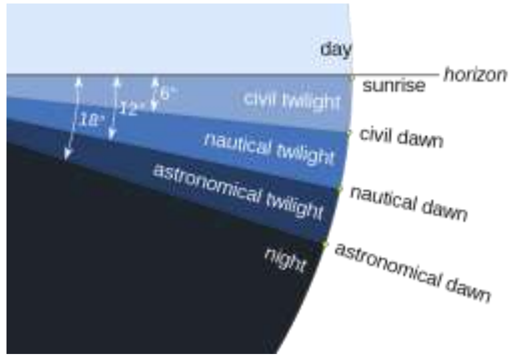

Figure 8. Morning twilight.

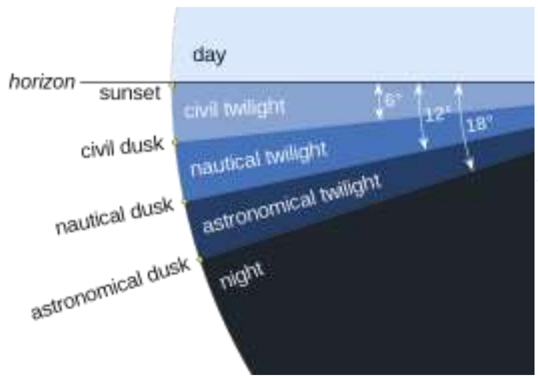

Figure 9. Evening twilight.

Information relating to morning, evening, and civil twilight times may be found at Time and Date (n.d.).

CONCLUSION AND RECOMMENDATIONS

The data categories and example data sets outlined above provide a roadmap for obtaining the data needed to develop the industry standards required to allow UAS operators to conduct low-altitude operations by rule instead of through a time and resource-intensive risk assessments or collecting and merging the data required to develop a comprehensive low-altitude risk assessment tool for use by UAS operators for highly complex operations that do not fit easily under the current rules. Identifying specific data elements inside of these data categories and establishing consistency among the data sets and data elements is beyond the scope of this effort. However, the effort outlined above could lead to research requirements for the ASSURE team and industry partners that would provide the missing data categories and elements needed to inform: (1) standards and practices for low-altitude operations and (2) policy regarding low-altitude UAS operations. The environmental conditions described by the elements of the roadmap, when combined with aircraft certification and standardized training of airmen, will provide a quantitative description of the potential risks of any CONOPs, allow for the application of standards or risk analyses to mitigate those identified risks, which will result in safer, low-altitude UAS operations.

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APPENDIX C – TABLETOP FRAMEWORK VALIDATION EXERCISE[4]

[4] Snapshots of Framework Spreadsheets Used in the Tabletop Framework Validation Exercise with Answers to Spreadsheet Questions for the CONOPS Resulting in Waiver 107W-2020-04368, Examples of Documentation Used in the Actual Part 107 Waiver Application, and Research Team Comments Annotated in Red

Form: Type of Applicant Information

Type of Applicant Information

Type of Applicant: ○ Public (Government) * ✖ Private (Civil) **

* If you have selected Public (Government) in response to the above question, please visit https://caps.faa.gov

** If you have selected Private (Civil) in response to the above question, please navigate further through this form

Form: Applicant Information

Applicant Information

Enter Applicant Information

Institution / Organization:	University of Alaska Fairbanks
Applicant Name:	Director Catherine Cahill
Address:	2160 Koyukuk Dr
City:	Fairbanks
State:	AK
Postal Code:	99709
Email:	cfcahill@alaska.edu
Telephone:	907-474-6905
Ext:	

Form: Declarations

Declarations

Enter Declarations Information

a. The applicant is an institution or organization located in the United States, a State, the District of Columbia, or a territory or possession of the United States. * ✖ Yes ○ No

b. The operations described in this application meet the definition of civil (commerical) aircraft operations as defined in 14 C.F.R. § 1.1. Note: For guidance see Advisory Circular (AC) 00 1.1 Government Aircraft Operations. * ✖ Yes ○ No

c. All flights made under the authority requested will be conducted under the limits of 14 C.F.R. § 107 with the exception of waivers granted for regulations under 14 C.F.R § 107.25. * ✖ Yes ○ No

d. Whoever in any matter within the jurisdiction of any department or agency of the United States knowingly or willfully falsifies, conceals, or covers up by any trick, scheme, or device a material fact, or who makes any false fictitious, or fraudulent statements or representatives, or entry may be defined up to $250,000 or imprisoned not more than 5 year, or if the offense involves international or domestic terrorism (as defined in 18 USC § 2331), imprisoned not more than 8 years or both (as defined in 18 USC § 1001, 3571). * ✖ Yes ○ No

e. Any information that is uploaded to this website is bound by the Freedom of Information Act (FOIA) and may be releasable. This requires compliance to FOIA and consent to the release of your information. If you do not consent to the release of your information you must contact us for further guidance. For more information, please visit http://www.foia.gov/. * ✖ Yes ○ No

Form: Point of Contact Information Form

Point of Contact Information Form

Enter Point of Contact Information

Primary Point of Contact Name:	Nicholas Adkins				
Address:	2160 Koyukuk Dr				
City:	Fairbanks	State:	AK	Postal Code:	99709
Telephone:	907-455-2000	Ext:		Email:	nadkins@alaska.edu
Secondary Point of Contact Name:	Thomas Elmer				
Address:	2160 Koyukuk Dr				
City:	Fairbanks	State:	AK	Postal Code:	99709
Telephone:	907-455-2000	Ext:		Email:	telmer@alaska.edu

Add a Tertiary Point of Contact?: Yes No

Form: Operational Description – Part 1

Operational Description - Part 1

Enter Operational Description Information

PROGRAM EXECUTIVE SUMMARY:

Please include the following information:

1. Information about the organization and applicant:
   a. Description of historical and current experience with UAS operations
   b. Description of pilot training, certification, and experience
   c. Description of UAS maintenance training, certification, and experience
   d. Description of the organization's Safety Management System (SMS)
2. Brief description of intended UAS operations to include rationale as to why a waiver is necessary

UAS OPERATIONS:

1. Operation strategy - Attach detailed descriptions for the items below:
   a. Site Survey: Attach File
   b. Mission Planning: Attach File
   c. Pre-Flight: Attach File
   d. Launch: Attach File
   e. En-Route: Attach File
   f. Recovery: Attach File
   g. Post Flight: Attach File
   h. Emergency Operation: Attach File

PROGRAM EXECUTIVE SUMMARY

1. The UAF team possess approximately 20 staff including pilots, operations experts, aviation mechanics, engineers, flight test experts, safety managers, payload experts, and scientists and can leverage other expertise from the University of Alaska Fairbanks, the research flagship of the University of Alaska, and two embedded contractors: Unmanned Systems Alaska and Norther Embedded Solutions. Many of the staff and contractors are retired military pilots or contractors who have flown a wide range of UAS, included Predators begore they were in an Air Force system, Shadows, ravens, ScanEagles, and other systems. All of ACUASI's pilots are current manned aircraft pilots in addition to being UAS remote pilots. The ACUASI

team flies UAS approximately 180 days a year and conducts all operations in a professional environment with a safety-first attitude.
ACUASI operates a variety of UAS ranging from small racing drones used in the Council for Opportunity and Education Science, Technology, Engineering, and Mathematics I (STEM II) program to a 300 lb., 16 ft wingspan, twin engine UAS (a Griffon Aerospace Outlaw SeaHunter) being used to assist Transport Canada in developing their concept of operations for operating UAS off of remote airports in the Canadian Arctic. ACUASI flies their UAS for diverse missions including aircraft Test and Evaluation, Detect and Avoid (DAA) system testing, command and control link testing, US Traffic Management (UTM) system testing, NAS integration at airports, high altitude (92,000') launches, marine and land mammal surveys, sea ice modeling, atmospheric sampling, wildfire surveillance, tidewater glacier mapping, and numerous other operations. The team has flown true Beyond Visual Line of Sight (BVLOS) operations using satellite command and control over the Arctic Ocean and in Canada. The UAF SeaHunter also has operated legally as an Instrument Flight Rules aircraft under Instrument Meteorological Conditions under Air Traffic Control in Canada.

Adkins, Nick: ACUASI Director of Operations: FAA Ratings include Commercial Pilot, Rotorcraft Helicopter Instrument, Single Engine Land Private, Part 107 Remote Pilot certificate; former Instructor Pilot for U.S. Army flight school (Chinook tandem rotor helicopter). Twenty-two years of aviation experience in piloting, maintaining, operations, training, dispatch, and management. 1700 flight hours. Professional instructor with extensive knowledge of instruction and evaluation techniques including being the primary advisor on Army pilot and aircrew training curriculums, aviation compliance issues, and use of aviation assets. Aviation Quality Assurance Officer responsible for oversight of US Army Alaska's aviation programs ensuring compliance with local, state, and federal laws and regulations for over 500 pilots and aircrew members for both manned and unmanned aircraft. Experience with a wide variety of ACUASI UAS including Responder, Ptarmigan, the suite of modified DJI products used for Detect and Avoid and Command and Control testing, Aeromapper, and others.

Parcell, Trevor: Pilot: Private Pilot - Single Engine Land Airplane; Part 107 Remote Pilot certificate; CASA Remote Pilot License. Ten years of operational test and evaluation experience both manned and unmanned aircraft. Seven years unmanned aircraft experience including ScanEagle, Nanook, Responder, Ptarmigan, and all other ACUASI small UAS

Westhoff, Matt: Pilot: Private Pilot- Single Engine Land Airplane; Part 107 Remote Pilot certificate. Certified Flight Instructor for RO-7B Shadow AS. Twelve years of unmanned aircraft experience including operating Shadows, Aerosonde Mk 4.7 Block Gs, and a variety of ACUASI AS including ScanEagle, Responder, Ptarmigan, and all other ACUASI small UAS

**What was not in our submission was the maintenance plan and training. In this framework we would add that we have an A&P Mechanic with an IA certification.

**Also, not in our original submission was an overview of our SMS program. We did have our risk matrices shown in Figure 5 and all of the hazard worksheets (not in this document) in our submission. Now, we would include a copy of our SMS manual.

Severity \ Likelihood	Extremely Improbable E	Extremely Remote D	Remote C	Probable B	Frequent A
Catastrophic 1	9				
Hazardous 2	2, 4, 5				
Major 3	10, 14	3			
Minor 4	7, 11, 15	13	8		
Minimal 5	12, 18	6, 17	1	16	

Figure 10. Risk Matrix

2. The goal of this aircraft operation is to perform aeronautical research to demonstrate the capabilities for beyond visual line of sight operations, while incorporating various technologies to mitigate safety risks. The operation will evaluate the detect and avoid capabilities of these technologies, ground-based and aircraft-based technologies such as uAvionix PingStation ADS-B receiver, evaluate the viability of Echodyne and Iris technologies. The intent of this aeronautical research study is to test sense and avoid technologies to show viable, safety and reliability to the FAA, with needed data to evaluate potential changes to existing regulations or the need for new regulations. The airspace for this study will be along the remote areas of the Trans-Alaska Pipeline System (TAPS) up to 400 feet above the ground.

OPERATIONAL SUMMARY:
The operation will utilize the following types of unmanned aircraft: Sky Front Perimeter. This aircraft will operate at less than 87 knots at or below 400 feet above the ground in proximity to the TAPS. The operations will last for up to two hours within class G airspace.

OPERATIONS AREA:
Planned operations will be along the TAPS highlighted in Figure 2. These operations will begin with short, within line of sight, and incrementally expanding to greater distances along the route with an ultimate operation encompassing the entire distance. The corridor starts at: 65°05'06.48" N/147°52'44.97 W, extending south to 65°01'32.96" N/148°44'57.86" W.

The eight points defining the given block of airspace are:
65° 5'23.33"N/147°51'43.43"W. 65° 5'08.26"N/147°51'13.86"W
65° 4'11.86"N/147°48'11.78"W. 65° 1'56.49"N/147°44'04.01"W
65° 1'09.88"N/147°45'43.20"W. 65° 3'28.85"N/147°49'47.37"W
65° 4'28.45"N/147°52'52.31"W. 65° 4'48.89"N/147°53'36.23"W

½ mile either side of and following the TAPS. The launch and recovery will be set up at the north end 65° 4'50.24"N/147°52'10.16"W (Beginning Point) also the location of the PIC and VO, the furthest point of travel will be the End Point 65° 1'44.65"N/147°45'24.06"W.

Figure 11. Operations Area

EMERGENCY PROCEDURES:

Perimeter UAS

Aviate, Navigate, and Communicate

Aviate, Navigate, and Communicate, is a workload management flow used by UAS pilots to prioritize duties.

These prioritizing concepts apply to all phases of flight and are especially important to follow in emergency procedures when the pilot is experiencing a high stress level.

Aviate:
• The UAS pilot's first priority is always to maintain control of the aircraft before any other action is taken.

Navigate:
• The UAS pilot's secondary priority is to orient the aircraft. Make sure the aircraft position and attitude are appropriate and in compliance with airspace restrictions and safety considerations.

Communicate:
• The UAS pilot's third priority is to communicate. As necessary, communicate aircraft status or airspace requests to the mission commander and ground crew. Always communicate briefly and concisely.

GPS FAILURE:
If GPS loss is experienced for 5 seconds while in mode that requires the GPS (Auto, Guided, Loiter, RTL, Circle, Position or Drift) mode, the UAS will initiate a Land (or Alt-Hold if FS GPS ENABLE is set to Alt-Hold).

Switch to "Stabilize Mode" and use the Spektrum controller to navigate the helicopter using the following procedure:
Use camera/sensor to determine the position of the aircraft:

- LANDMARK- Identify a landmark on the surface using the sensor and descend or ascend to a safe altitude
- LANDMARK - Orient oneself and bring the helicopter home using terrain features.

GCS FAILURE:
The UAS will Return to Launch if comms lost with Manual Control Console (MCC). Can be set to continue mission IF GCS has link AND on AUTO mission. Or if GPS failsafe is triggered it will land in place - ref responder UAV operator handbook page 35.

COMMUNICATION FAILURE:
The UAS will continue its mission or Return to Launch (RT) depending on mission settings.
(see above)

Lost Communications Failsafe: In Mission Planner's Advanced Parameter List, the operator will set the FS_GCS_ENABLE parameter to one of the two setting below:

- "Enable" and always "RTL" in event of loss of contact.

- "Continue Mission in AUTO" mode.

If Ground Control Station contact has been lost for at least 5 seconds the following will happen:

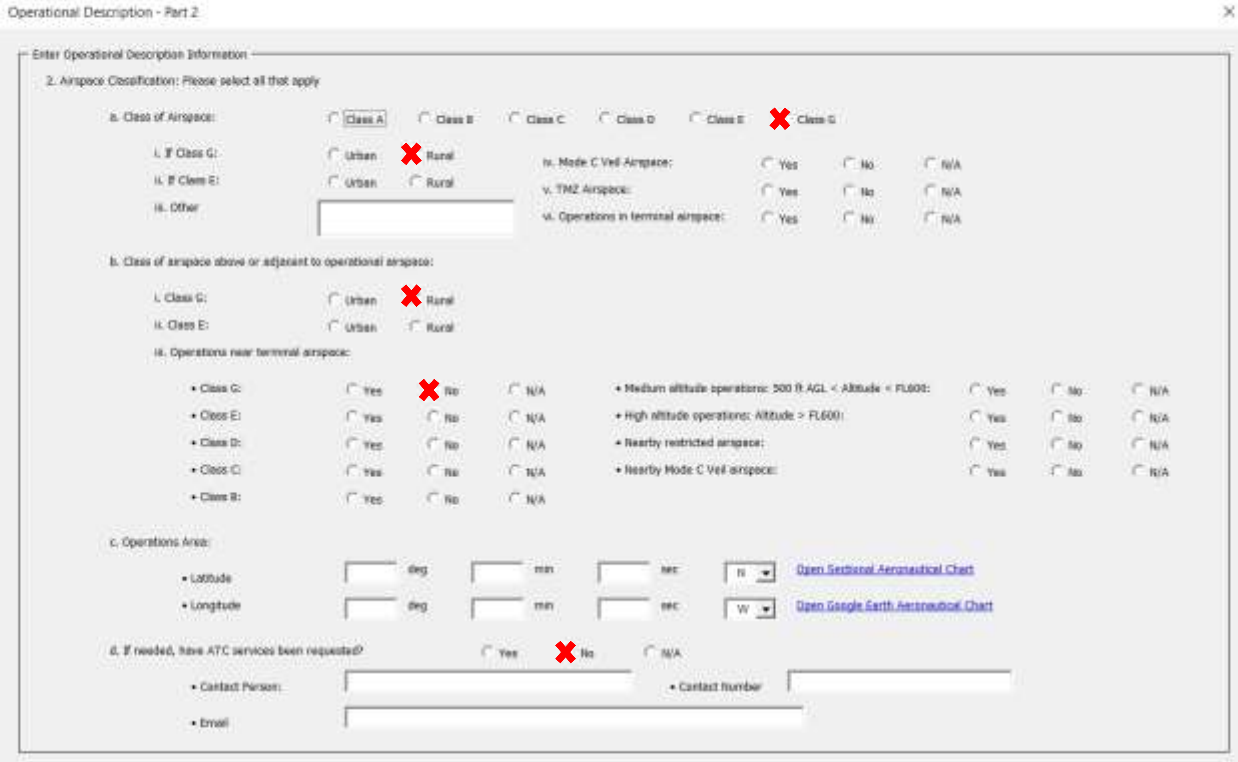
- RTL- if GPS is stable.
- LAND - if GPS is not stable.
- Continue with the Mission - if in AUTO mode and have set the GCS Failsafe
- Options to (Enabled continue in auto mode).

If the failsafe clears (contact with the GCS is restored) the UAS will remain in RTL or LAND mode. It will not automatically return to the flight mode that was active before the failsafe was triggered. This means that the operator would have to manually re-take control of the UA and set flight mode again back to stabilize.

1. UAF pre-programs the onboard computer to do one of two things. One is to return to a pre-determined spot. That location at the SCC site would be the launch location. For longer flights it could be a service road. The other option is to abort and land in place. The drone is also equipped with a flight termination system as a failsafe which will commence auto-land.

2. The ground control station would be the first to notify the PIC of an abnormal operation. The UAS is programmed to land rather than fly-away in a worst-case scenario.

Form: Operational Description – Part 2



Operational Description - Part 2

Enter Operational Description Information

2. Airspace Classification: Please select all that apply

a. Class of Airspace: Class A | Class B | Class C | Class D | Class E | ✗ Class G

i. If Class G: Urban | ✗ Rural
ii. If Class E: Urban | Rural
iii. Other: [ ]

iv. Mode C Veil Airspace: Yes | No | N/A
v. TMZ Airspace: Yes | No | N/A
vi. Operations in terminal airspace: Yes | No | N/A

b. Class of airspace above or adjacent to operational airspace:

i. Class G: Urban | ✗ Rural
ii. Class E: Urban | Rural
iii. Operations near terminal airspace:

- Class G: Yes | ✗ No | N/A
- Class E: Yes | No | N/A
- Class D: Yes | No | N/A
- Class C: Yes | No | N/A
- Class B: Yes | No | N/A
- Medium altitude operations: 500 ft AGL < Altitude < FL600: Yes | No | N/A
- High altitude operations: Altitude > FL600: Yes | No | N/A
- Nearby restricted airspace: Yes | No | N/A
- Nearby Mode C Veil airspace: Yes | No | N/A

c. Operations Area:

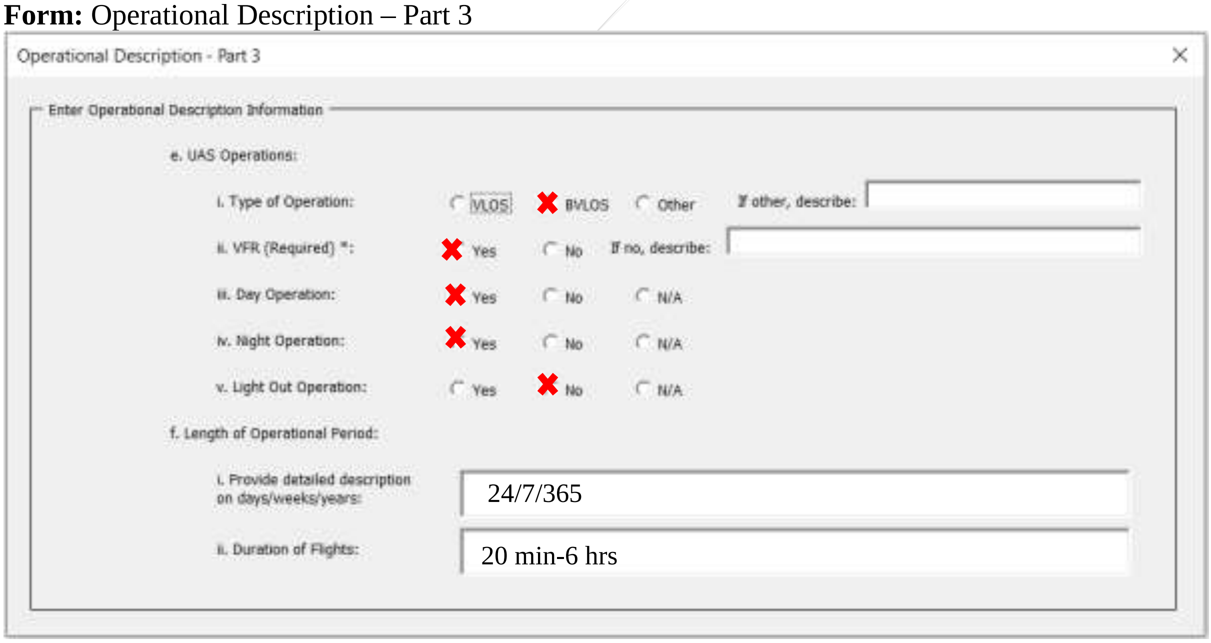
- Latitude: [ ] deg [ ] min [ ] sec [N] Open Sectional Aeronautical Chart
- Longitude: [ ] deg [ ] min [ ] sec [W] Open Google Earth Aeronautical Chart

d. If needed, have ATC services been requested? Yes | ✗ No | N/A

- Contact Person: [ ] • Contact Number [ ]
- Email [ ]

** C. This needs to have area layout possible. Our airspace for instance was 4 miles by 1.25 mile. This appears to be asking for a center point and radius.

Form: Operational Description – Part 3



Operational Description - Part 3

Enter Operational Description Information

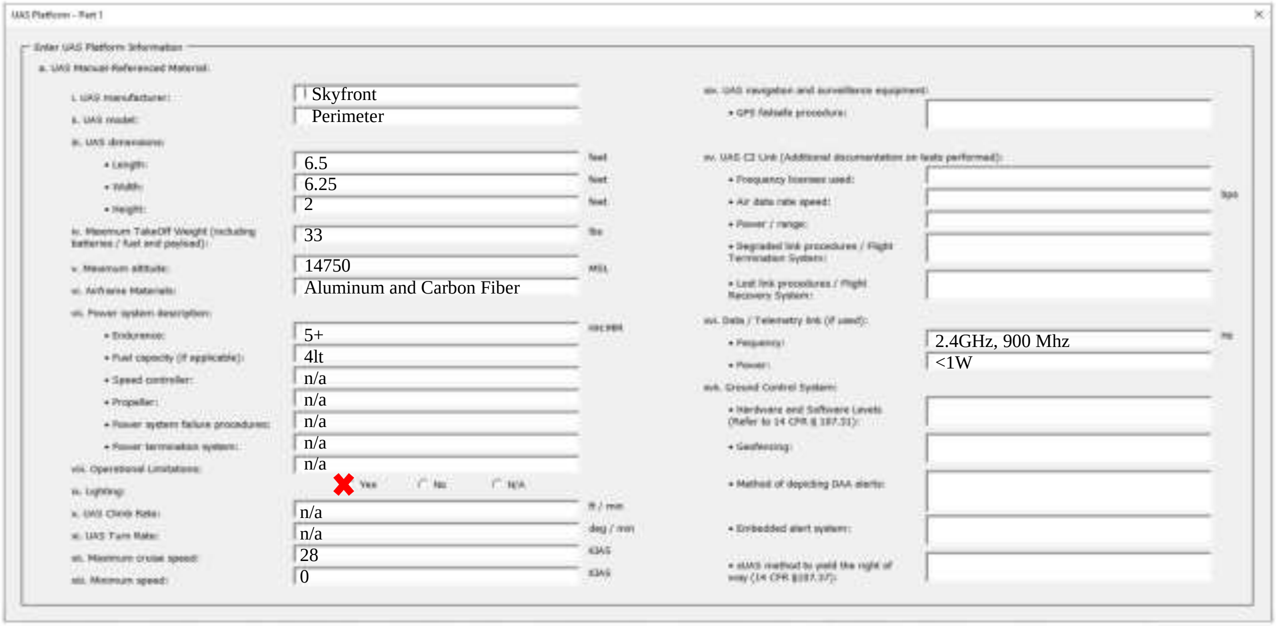
e. UAS Operations:

i. Type of Operation: VLOS | ✗ BVLOS | Other — If other, describe: [ ]
ii. VFR (Required) *: ✗ Yes | No — If no, describe: [ ]
iii. Day Operation: ✗ Yes | No | N/A
iv. Night Operation: ✗ Yes | No | N/A
v. Light Out Operation: Yes | ✗ No | N/A

f. Length of Operational Period:

i. Provide detailed description on days/weeks/years: 24/7/365
ii. Duration of Flights: 20 min-6 hrs

Form: UAS Platform – Part 1



xiv. GPS FAILURE:

If GPS loss is experienced for 5 seconds while in mode that requires the GPS (Auto, Guided, Loiter, RTL, Circle, Position or Drift) mode, the UAS will initiate a Land (or Alt-Hold if FS GPS ENABLE is set to Alt-Hold).

Switch to "Stabilize Mode" and use the Spektrum controller to navigate the helicopter using the following procedure:

Use camera/sensor to determine the position of the aircraft:

- LANDMARK- Identify a landmark on the surface using the sensor and descend or ascend to a safe altitude
- LANDMARK - Orient oneself and bring the helicopter home using terrain features.

xv. ISM

COMMUNICATION FAILURE:

The UAS will continue its mission or Return to Launch (RTL) depending on mission settings. (see above)

Lost Communications Failsafe: In Mission Planner's Advanced Parameter List, the operator will set the FS_GCS_ENABLE parameter to one of the two setting below:

- "Enable" and always "RTL" in event of loss of contact.
- "Continue Mission in AUTO" mode.

If Ground Control Station contact has been lost for at least 5 seconds the following will happen:

- RTL- if GPS is stable.
- LAND - if GPS is not stable.
- Continue with the Mission - if in AUTO mode and have set the GCS Failsafe
- Options to (Enabled continue in auto mode).

If the failsafe clears (contact with the GCS is restored) the UAS will remain in RTL or LAND mode. It will not automatically return to the flight mode that was active before the failsafe was triggered. This means that the operator would have to manually re-take control of the UA and set flight mode again back to stabilize.
1. UAF pre-programs the onboard computer to do one of two things. One is to return to a pre-determined spot. That location at the SCC site would be the launch location. For longer flights it could be a service road. The other option is to abort and land in place. The drone is also equipped with a flight termination system as a failsafe which will commence auto-land.

2. The ground control station would be the first to notify the PIC of an abnormal operation. The UAS is programmed to land rather than fly-away in a worst-case scenario.

xvii. A It is unclear what you are looking for here there is nothing in 107.31 that gives guidance to Hardware and Software Levels.

xvii. B Echodyne Ground Based Radar.

xvii. C The Ground based radar will be observed by both the pilot and visual observer. When a manned aircraft is determined to be in conflict the appropriate avoidance (descend, turn, etc.) will be commanded to the UA.

Form: UAS Platform – Part 2

UAS Platform - Part 2

Enter UAS Platform Information

a. UAS Manual-Referenced Material (continued)

xviii. UAS Software Description:	
xix. UAS DAA Systems used:	Iris Automation Casia, Echodyne MESA ground-based radar
xx. UAS Payload capacity:	
• Description:	No separate payload
• Payload securing:	
xxi. UAS safety mitigations (e.g. parachutes, airbags, system redundancies etc.):	Battery backup to fuel system, etc.
xxii. UAS Maintenance:	
• Brief description on how this will be accomplished. Ex: Determination of airworthiness:	Not in original submission – now would put in A&P mechanic responsible for maintaining aircraft.

xviii.

ELECTRONICS, SOFTWARE AND FIRMWARE	
Autopilot Firmware	Janus Autopilot™. Proprietary. PX4-based.
Engine Control Firmware and Electronics	Proprietary.
Autopilot Electronics	Proprietary. Pixhawk-based. Hardened and protected.
Country of Origin for All Software/Firmware	United States of America
GROUND CONTROL STATION	
Ground Control Software	Janus Ground Control Station™ (jGCS). Proprietary.
Ground Control Hardware	QGroundControl-based with engine telemetry and control. Windows 10 Laptop

Form: Flight Aircraft Qualifications

Flight Aircrew Qualifications

Enter Flight Aircrew Qualification Information

a. Operators (RPIC) involved: Yes / No / N/A

b. Experience:

c. Describe specific training provided by the organization (if any):

i. Recurrent training:

ii. Other training:

d. Credentials and Certificates: Yes / No / N/A

For inputting credentials and certificates for additional pilots, click here

i. Private (Written):

ii. Private (Certified):

iii. Instrument:

iv. Commercial:

v. Air Transport:

vi. Remote Pilot - sUAS: Yes / No / N/A

vii. DoD certified / trained:

viii. Other certified training:

ix. Trained on FAR Part 91:

x. Medical certification class:

• FAA or DoD equivalent:

• Currency status:

xi. Duty time restrictions:

xii. UAS Control:

• Single: Yes / No / N/A

• If not single, provide additional information:

• Number of UAS controlled simultaneously:

x. Additional remarks or Special circumstances:

b. Experience:

Adkins, Nick: ACUASI Director of Operations: FAA Ratings include Commercial Pilot, Rotorcraft Helicopter Instrument, Single Engine Land Private, Part 107 Remote Pilot certificate; former Instructor Pilot for U.S. Army flight school (Chinook tandem rotor helicopter). Twenty-two years of aviation experience in piloting, maintaining, operations, training, dispatch, and management. 1700 flight hours. Professional instructor with extensive knowledge of instruction and evaluation techniques including being the primary advisor on Army pilot and aircrew training curriculums, aviation compliance issues, and use of aviation assets. Aviation Quality Assurance Officer responsible for oversight of the US Army Alaska's aviation programs ensuring compliance with local, state, and federal laws and regulations for over 500 pilots and aircrew members for both manned and unmanned aircraft. Experience with a wide variety of ACUASI UAS including Responder, Ptarmigan, the suite of modified DJI products used for Detect and Avoid and Command and Control testing, Aeromapper, and others.

Parcell, Trevor: Pilot: Private Pilot - Single Engine Land Airplane; Part 107 Remote Pilot certificate; CASA Remote Pilot License. Ten years of operational test and evaluation experience both manned and unmanned aircraft. Seven years unmanned aircraft experience including ScanEagle, Nanook, Responder, Ptarmigan, and all other ACUASI small UAS

Westhoff, Matt: Pilot: Private Pilot- Single Engine Land Airplane; Part 107 Remote Pilot certificate. Certified Flight Instructor for RO-7B Shadow AS. Twelve years of unmanned aircraft experience including operating Shadows, Aerosonde Mk 4.7 Block Gs, and a variety of ACUASI AS including ScanEagle, Responder, Ptarmigan, and all other ACUASI small UAS

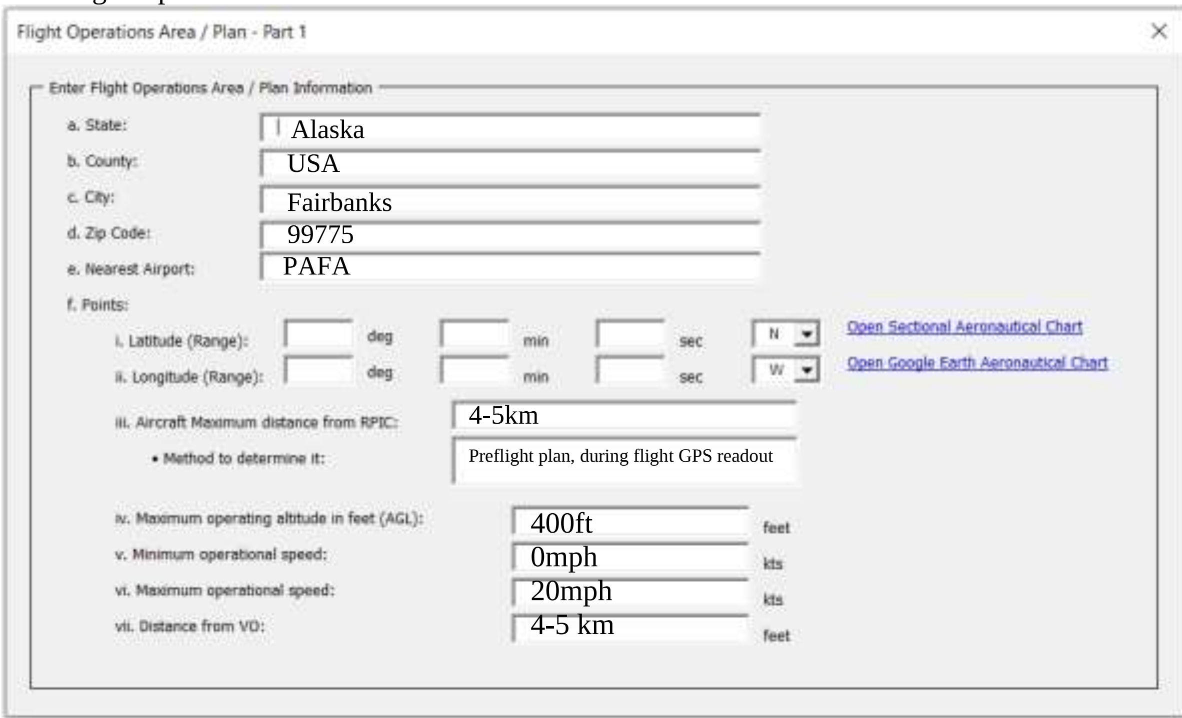
c. Describe the training level of each crew member:

All pilots are certified Private pilot or higher as well as being 107 certified Remote Pilots. Specific training for ACUASI US will be conducted in a classroom and practical tests as determined by ACUASI instructors. ACUASI will administer an oral and practical flight evaluation. Pilots must maintain currency in a traditional aircraft and conduct recurring training on flight simulators.

d. Credentials and Certificates

Yes, for Nick it is multiple certifications, FAA - commercial pilot, rotorcraft helicopter instrument, single engine land private, remote pilot certificate and DoD - Including being an Instructor Pilot. Current medical certificate

Form: Flight Operations Area/Plan – Part 1



Flight Operations Area / Plan - Part 1

Enter Flight Operations Area / Plan Information

a. State: Alaska

b. County: USA

c. City: Fairbanks

d. Zip Code: 99775

e. Nearest Airport: PAFA

f. Points:

i. Latitude (Range): deg min sec N

ii. Longitude (Range): deg min sec W

Open Sectional Aeronautical Chart

Open Google Earth Aeronautical Chart

iii. Aircraft Maximum distance from RPIC: 4-5km

• Method to determine it: Preflight plan, during flight GPS readout

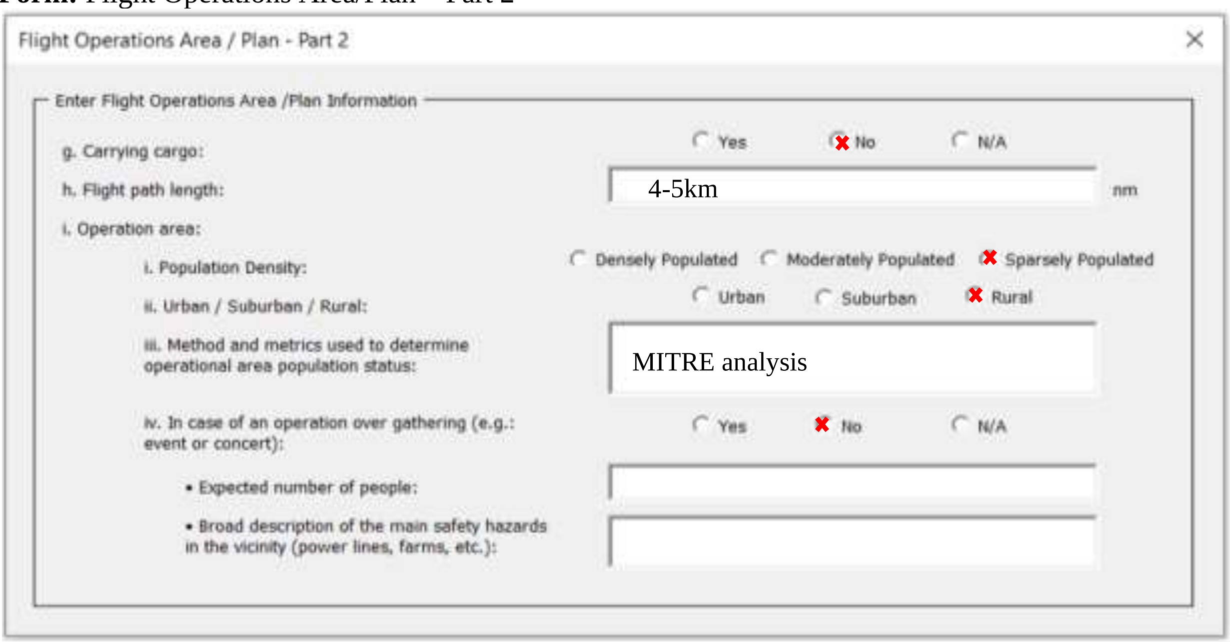
iv. Maximum operating altitude in feet (AGL): 400ft feet

v. Minimum operational speed: 0mph kts

vi. Maximum operational speed: 20mph kts

vii. Distance from VO: 4-5 km feet

Form: Flight Operations Area/Plan – Part 2



Flight Operations Area / Plan - Part 2

Enter Flight Operations Area /Plan Information

g. Carrying cargo: Yes / No (selected) / N/A

h. Flight path length: 4-5km nm

i. Operation area:

i. Population Density: Densely Populated / Moderately Populated / Sparsely Populated (selected)

ii. Urban / Suburban / Rural: Urban / Suburban / Rural (selected)

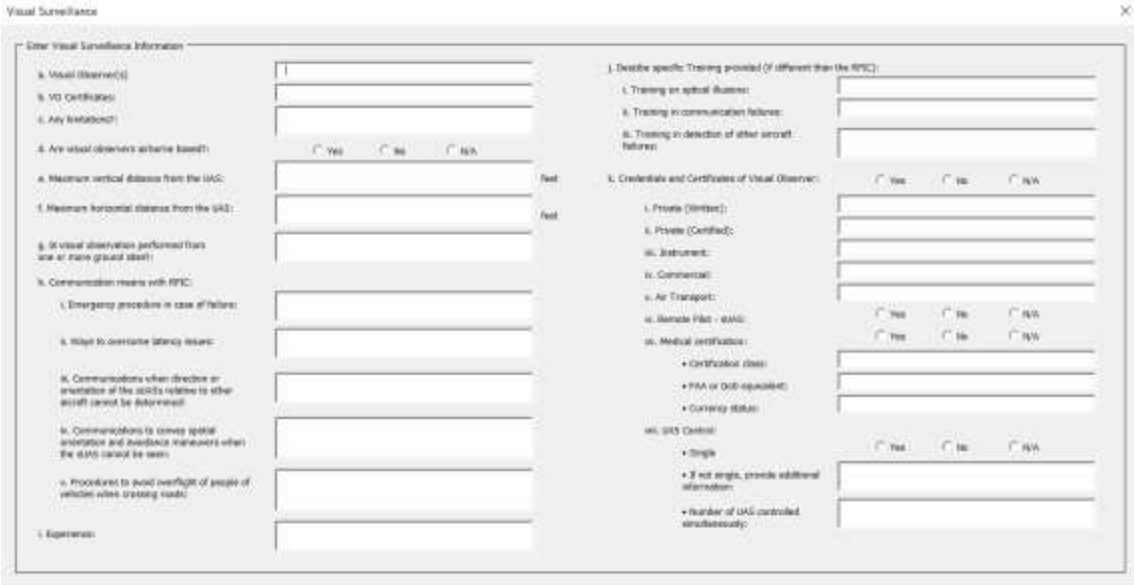
iii. Method and metrics used to determine operational area population status: MITRE analysis

iv. In case of an operation over gathering (e.g.: event or concert): Yes / No (selected) / N/A

• Expected number of people:

• Broad description of the main safety hazards in the vicinity (power lines, farms, etc.):

Form: Visual Surveillance



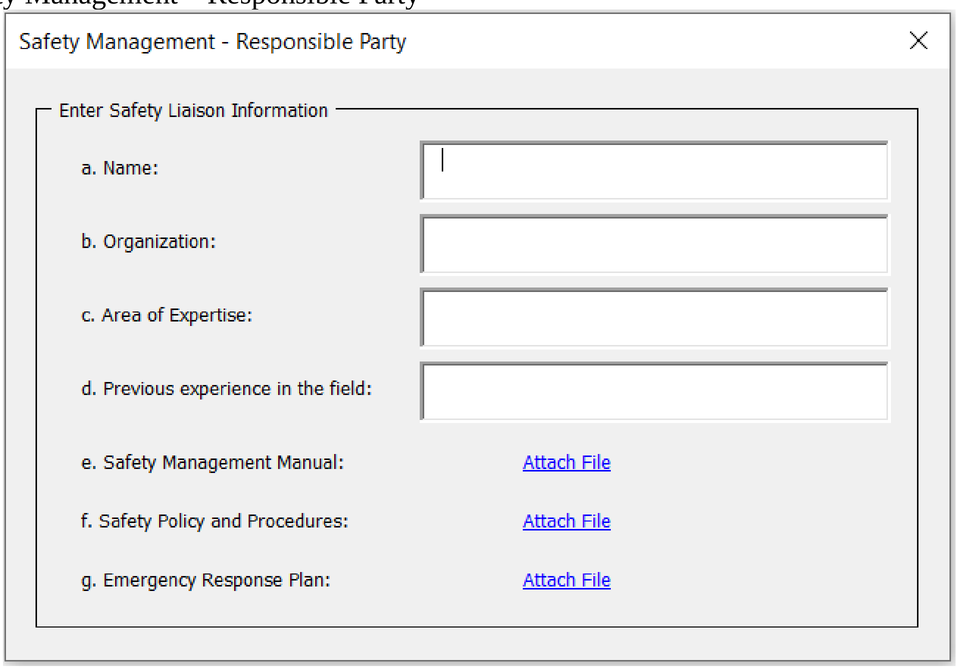
Visual Surveillance

Enter Visual Surveillance Information

a. Visual Observer(s):
b. VO Certificates:
c. Any limitations?:
d. Are visual observers airborne based?: Yes / No / N/A
e. Maximum vertical distance from the UAS: Feet
f. Maximum horizontal distance from the UAS: Feet
g. Is visual observation performed from one or more ground sites?:
h. Communication means with RPIC:
i. Emergency procedure in case of failure:
ii. Ways to overcome latency issues:
iii. Communications when direction or orientation of the sUASs relative to other aircraft cannot be determined:
iv. Communications to convey spatial orientation and avoidance maneuvers when the sUAS cannot be seen:
v. Procedures to avoid overflight of people of vehicles when crossing roads:
i. Experience:
j. Describe specific Training provided (if different than the RPIC):
i. Training on optical illusions:
ii. Training in communication failures:
iii. Training in detection of other aircraft failures:
k. Credentials and Certificates of Visual Observer: Yes / No / N/A
i. Private (Written):
ii. Private (Certified):
iii. Instrument:
iv. Commercial:
v. Air Transport:
vi. Remote Pilot - sUAS: Yes / No / N/A
vii. Medical certification: Yes / No / N/A
• Certification class:
• FAA or DoD equivalent:
• Currency status:
viii. UAS Control:
• Single: Yes / No / N/A
• If not single, provide additional information:
• Number of UAS controlled simultaneously:

a. One-but for this operation, the VO is watching the DAA visualization screens and standing next to the Remote Pilot in Command (RPIC).
k. See experience on pilot worksheets – private pilot minimum, remote pilot certification, FAA Medical Certificate – current.

Form: Safety Management – Responsible Party



Safety Management - Responsible Party

Enter Safety Liaison Information

a. Name:
b. Organization:
c. Area of Expertise:
d. Previous experience in the field:
e. Safety Management Manual: Attach File
f. Safety Policy and Procedures: Attach File
g. Emergency Response Plan: Attach File

** This was not identified specifically as a separate person in the waiver or application. We can fill in for future requests.

Form: Technical Issue with UAS – Part 1


Technical Issue with UAS - Part 1

Enter Technical Issue with UAS Information

a. UAS Electrical Failure:

i. Within your ConOps, consider the consequences of a UAS electrical failure. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes / No

b. UAS flight control component failure / malfunction:

i. Within your ConOps, consider the consequences of a UAS flight control component failure / malfunction. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes / No

c. UAS flight control system operational error, malfunction, or failure to meet the expected performance:

i. Within your ConOps, consider the consequences of a UAS flight control system operational error, malfunction, or failure to meet the expected performance. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes / No

d. UAS system design / not fitted to the required performance for the operation. For instance, UAS expected performance does not match required operational performance as indicated in the ConOps:

i. Within your ConOps, consider the consequences of a UAS system design not fitted to the required performance for the operation. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes / No

e. The communication's link between the aircraft and the control station does not work as expected:

i. Within your ConOps, consider the consequences of the communication's link between the aircraft and the operator not working as expected. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes / No

**Most of these technical hazards were included in the UAS Hazard Analysis worksheet in the submission.

	Hazard Analysis Workbook Summary	Initial Risk	Residual Risk
1	Loss of UAS Command and Control Link	C3	C5
2	Loss of navigational control	E2	E2
3	Propulsion System Failure	C3	D3
4	sUAS Observer loses visual contact with UA	D2	E2
5	sUAS Fly Away	E2	E2
6	Lost comms between sUAS PIC and ATC	D5	D5
7	Lost comms between PIC and observers	C4	E4
8	Loss of Link with Tracking Antenna	B2	C4
9	Mid-Air Collision	E1	E1
10	Unknown Winds Aloft	B3	E3
11	Low or bingo battery prior to landing	E4	E4
12	Frequency Interference	D5	E5
13	Non-crew member interruption of flight crew	C3	D4
14	sUA collision with people inside takeoff/Landing area	E3	E3
15	sUA flight into pipeline	D3	E4
16	Unforecasted Weather	B5	B5
17	Loss of Data due to sUA fly away	D5	D5
18	Loss of Data due to sUA fly away	E1	E5

Form: Technical Issue with UAS – Part 2


Technical Issue with UAS – Part 2

Enter Technical issue with UAS Information

f. Communication's link between the aircraft and the operator failure / malfunction (momentary loss):

i. Within your ConOps, consider the consequences of a communication's link between the aircraft and the operator system experiencing a momentary loss. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

g. Frequencies interference in the communication's link between the aircraft and the operator which impair the correct operation of your UAS:

i. Within your ConOps, consider the consequences of frequencies interference in the communication's link between the aircraft and the operator which impair the correct operation of your UAS. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

h. UAS sensor system failure / malfunction:

i. Within your ConOps, consider the consequences of a UAS sensor system failure / malfunction. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

i. UAS propulsion system failure / malfunction:

i. Within your ConOps, consider the consequences of a UAS propulsion system failure / malfunction. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

j. UAS navigation system failure / malfunction:

i. Within your ConOps, consider the consequences of a UAS navigation system failure / malfunction. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

** These were included in the UAS Hazard Analysis Worksheet in the submission.

	Hazard Analysis Workbook Summary	Initial Risk	Residual Risk
1	Loss of UAS Command and Control Link	C3	C5
2	Loss of navigational control	E2	E2
3	Propulsion System Failure	C3	D3
4	sUAS Observer loses visual contact with UA	D2	E2
5	sUAS Fly Away	E2	E2
6	Lost comms between sUAS PIC and ATC	D5	D5
7	Lost comms between PIC and observers	C4	E4
8	Loss of Link with Tracking Antenna	B2	C4
9	Mid-Air Collision	E1	E1
10	Unknown Winds Aloft	B3	E3
11	Low or bingo battery prior to landing	E4	E4
12	Frequency Interference	D5	E5
13	Non-crew member interruption of flight crew	C3	D4
14	sUA collision with people inside takeoff/Landing area	E3	E3
15	sUA flight into pipeline	D3	E4
16	Unforecasted Weather	B5	B5
17	Loss of Data due to sUA fly away	D5	D5
18	Loss of Data due to sUA fly away	E1	E5

Form: Technical Issue with UAS – Part 3

Technical Issue with UAS - Part 3

Enter Technical issue with UAS Information

k. UAS software error (other than the Flight Control System):

i. Within your ConOps, consider the consequences of a UAS software error, other than the Flight Control System. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

l. UAS Flight Control System failure / error:

i. Within your ConOps, consider the consequences of a UAS Flight Control System failure / error. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

m. UAS supporting system failure / malfunction (non-control component). For instance: Weather warning system does not provide the appropriate information, as per the ConOps:

i. Within your ConOps, consider the consequences of a UAS supporting system failure / malfunction. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

n. UAS loss of the GPS navigation system:

i. Within your ConOps, consider the consequences of a UAS loss of GPS. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

o. GCS power / electrical system failure:

i. Within your ConOps, consider the consequences of a UAS power or electrical system failure. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

** These were included in the UAS Hazard Analysis Worksheet in the submission.

	Hazard Analysis Workbook Summary	Initial Risk	Residual Risk
1	Loss of UAS Command and Control Link	C3	C5
2	Loss of navigational control	E2	E2
3	Propulsion System Failure	C3	D3
4	sUAS Observer loses visual contact with UA	D2	E2
5	sUAS Fly Away	E2	E2
6	Lost comms between sUAS PIC and ATC	D5	D5
7	Lost comms between PIC and observers	C4	E4
8	Loss of Link with Tracking Antenna	B2	C4
9	Mid-Air Collision	E1	E1
10	Unknown Winds Aloft	B3	E3
11	Low or bingo battery prior to landing	E4	E4
12	Frequency Interference	D5	E5
13	Non-crew member interruption of flight crew	C3	D4
14	sUA collision with people inside takeoff/Landing area	E3	E3
15	sUA flight into pipeline	D3	E4
16	Unforecasted Weather	B5	B5
17	Loss of Data due to sUA fly away	D5	D5
18	Loss of Data due to sUA fly away	E1	E5

Form: Technical Issue with UAS – Part 4

Technical Issue with UAS - Part 4

Enter Technical issue with UAS information

p. GCS total system failure - Software (Excluding power / electrical failure):

i. Within your ConOps, consider the consequences of a GCS total system failure - Software. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

q. GCS total system failure - Hardware (Excluding power / electrical failure):

i. Within your ConOps, consider the consequences of a GCS total system failure - Hardware. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

r. Not equipped with DAA or DAA not functional:

i. Within your ConOps, consider the consequences of an aircraft not equipped with DAA or DAA not functional. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the

ii. Based on your answer, is this a hazard of your operation?: Yes No

s. Airframe structural damage undetected before flying, for instance, from a previous rough landing:

i. Within your ConOps, consider the consequences of the airframe having a structural damage which has not been detected before flying. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or

ii. Based on your answer, is this a hazard of your operation?: Yes No

t. UAS not equipped with GBDAA or GBDAA non functional or out of range:

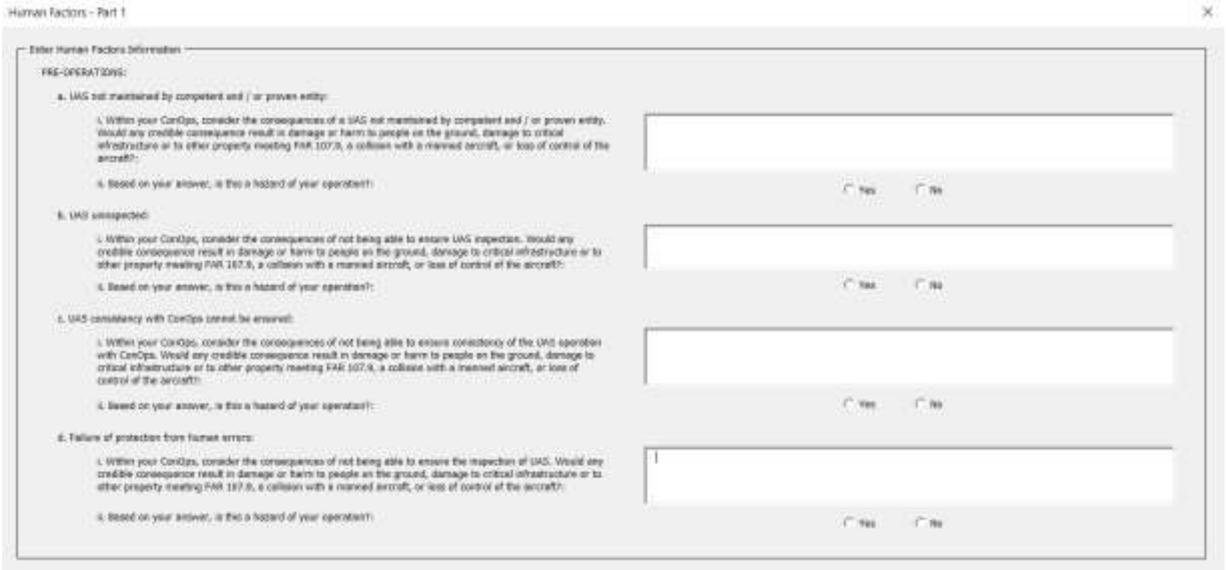
i. Within your ConOps, consider the consequences of a UAS not equipped with GBDAA or GBDAA non functional or out of range. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of

ii. Based on your answer, is this a hazard of your operation?: Yes No

** These were included in the UAS Hazard Analysis Worksheet in the submission.

	Hazard Analysis Workbook Summary	Initial Risk	Residual Risk
1	Loss of UAS Command and Control Link	C3	C5
2	Loss of navigational control	E2	E2
3	Propulsion System Failure	C3	D3
4	sUAS Observer loses visual contact with UA	D2	E2
5	sUAS Fly Away	E2	E2
6	Lost comms between sUAS PIC and ATC	D5	D5
7	Lost comms between PIC and observers	C4	E4
8	Loss of Link with Tracking Antenna	B2	C4
9	Mid-Air Collision	E1	E1
10	Unknown Winds Aloft	B3	E3
11	Low or bingo battery prior to landing	E4	E4
12	Frequency Interference	D5	E5
13	Non-crew member interruption of flight crew	C3	D4
14	sUA collision with people inside takeoff/Landing area	E3	E3
15	sUA flight into pipeline	D3	E4
16	Unforecasted Weather	B5	B5
17	Loss of Data due to sUA fly away	D5	D5
18	Loss of Data due to sUA fly away	E1	E5

Form: Human Factors – Part 1



Human Factors - Part 1

Enter Human Factors Information

PRE-OPERATIONS:

a. UAS not maintained by competent and / or proven entity:

i. Within your ConOps, consider the consequences of a UAS not maintained by competent and / or proven entity. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

b. UAS uninspected:

i. Within your ConOps, consider the consequences of not being able to ensure UAS inspection. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

c. UAS consistency with ConOps cannot be ensured:

i. Within your ConOps, consider the consequences of not being able to ensure consistency of the UAS operation with ConOps. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

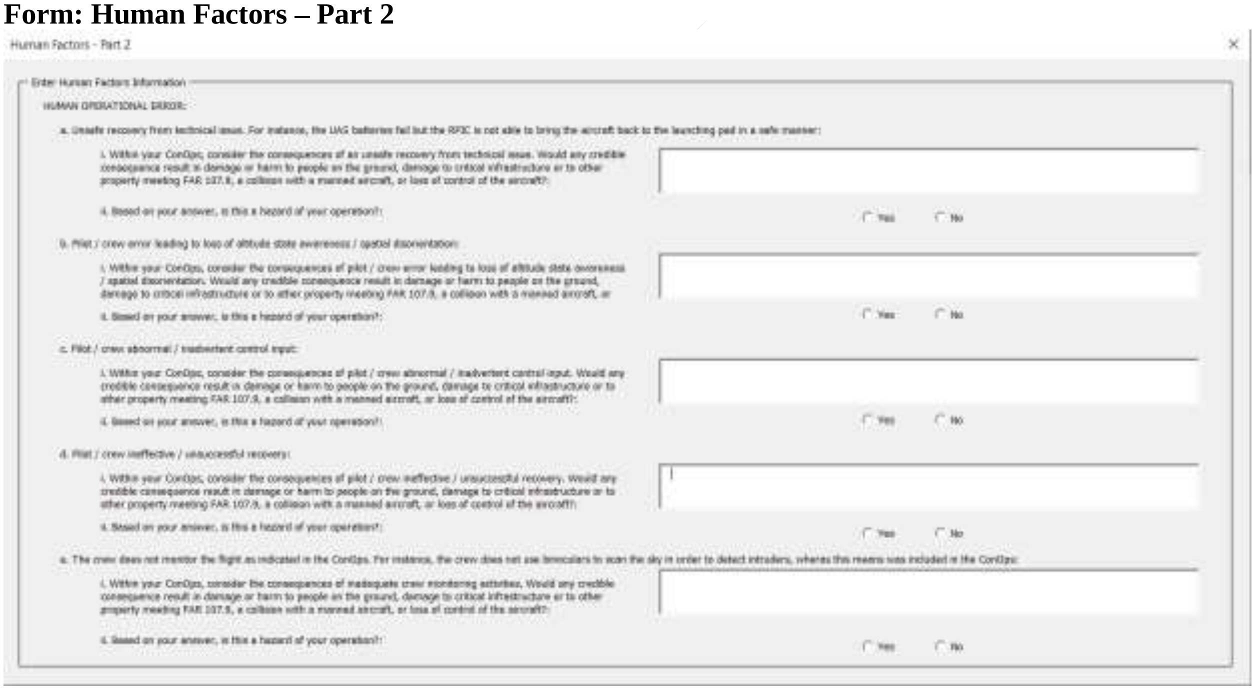
d. Failure of protection from human errors:

i. Within your ConOps, consider the consequences of not being able to ensure the inspection of UAS. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

** We did not include these items in our waiver submission. Based on our operational expertise, we have checklists and other guidance to ensure compliance with the manuals, CONOPS, and other factors that ensure mission success and minimize human error. We also have significant UAS maintenance experience (and A&P on staff) which is why we did not explicitly address the answers to these questions in the waiver submission.

Form: Human Factors – Part 2



Human Factors - Part 2

Enter Human Factors Information

HUMAN OPERATIONAL ERROR:

a. Unsafe recovery from technical issues. For instance, the UAS batteries fail but the RPIC is not able to bring the aircraft back to the launching pad in a safe manner:

i. Within your ConOps, consider the consequences of an unsafe recovery from technical issue. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

b. Pilot / crew error leading to loss of altitude state awareness / spatial disorientation:

i. Within your ConOps, consider the consequences of pilot / crew error leading to loss of altitude state awareness / spatial disorientation. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or

ii. Based on your answer, is this a hazard of your operation?: Yes No

c. Pilot / crew abnormal / inadvertent control input:

i. Within your ConOps, consider the consequences of pilot / crew abnormal / inadvertent control input. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

d. Pilot / crew ineffective / unsuccessful recovery:

i. Within your ConOps, consider the consequences of pilot / crew ineffective / unsuccessful recovery. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

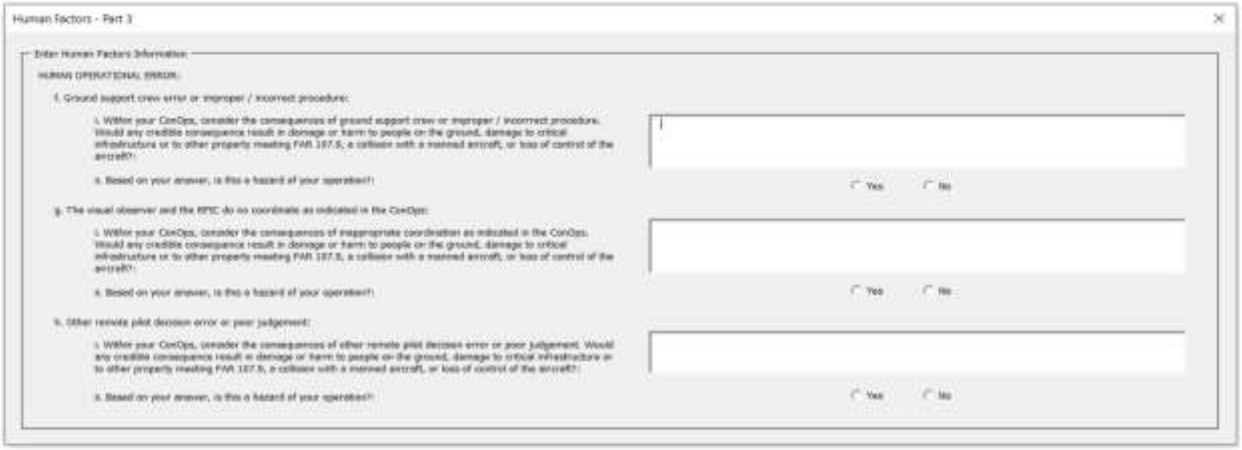
e. The crew does not monitor the flight as indicated in the ConOps. For instance, the crew does not use binoculars to scan the sky in order to detect intruders, whereas this means was included in the ConOps:

i. Within your ConOps, consider the consequences of inadequate crew monitoring activities. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

** We did not include these items in our waiver submission. Based on our operational expertise, we have checklists and other guidance to ensure compliance with the manuals, CONOPS, and other factors that ensure mission success and minimize human error.

Form: Human Factors – Part 3


Human Factors - Part 3

Enter Human Factors Information

HUMAN OPERATIONAL ERROR:

f. Ground support crew error or improper / incorrect procedure:

i. Within your ConOps, consider the consequences of ground support crew or improper / incorrect procedure. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

g. The visual observer and the RPIC do no coordinate as indicated in the ConOps:

i. Within your ConOps, consider the consequences of inappropriate coordination as indicated in the ConOps. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

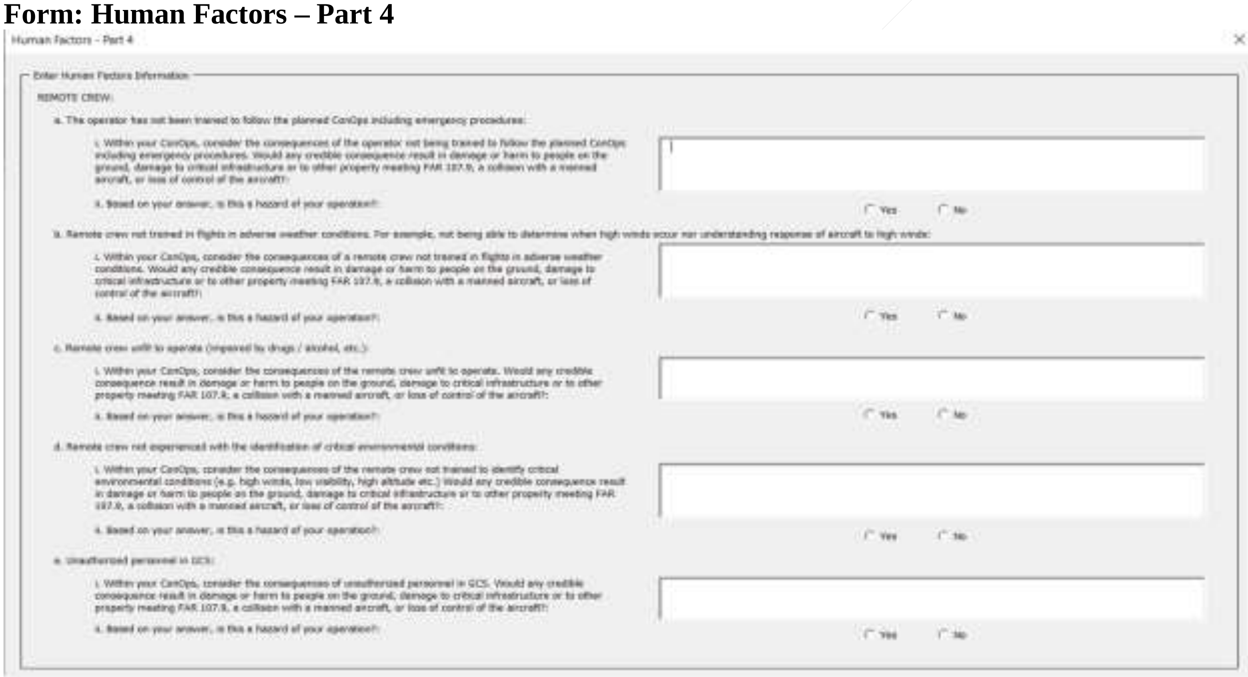
h. Other remote pilot decision error or poor judgement:

i. Within your ConOps, consider the consequences of other remote pilot decision error or poor judgement. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

** We did not include these items in our waiver submission. Based on our operational expertise, we have checklists and other guidance to ensure compliance with the manuals, CONOPS, and other factors that ensure mission success and minimize human error.

Form: Human Factors – Part 4


Human Factors - Part 4

Enter Human Factors Information

REMOTE CREW:

a. The operator has not been trained to follow the planned ConOps including emergency procedures:

i. Within your ConOps, consider the consequences of the operator not being trained to follow the planned ConOps including emergency procedures. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

b. Remote crew not trained in flights in adverse weather conditions. For example, not being able to determine when high winds occur nor understanding response of aircraft to high winds:

i. Within your ConOps, consider the consequences of a remote crew not trained in flights in adverse weather conditions. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

c. Remote crew unfit to operate (impaired by drugs / alcohol, etc.):

i. Within your ConOps, consider the consequences of the remote crew unfit to operate. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

d. Remote crew not experienced with the identification of critical environmental conditions:

i. Within your ConOps, consider the consequences of the remote crew not trained to identify critical environmental conditions (e.g. high winds, low visibility, high altitude etc.) Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

e. Unauthorized personnel in GCS:

i. Within your ConOps, consider the consequences of unauthorized personnel in GCS. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: Yes No

** a-c. We did not include these items in our waiver submission. Based on our operational expertise, we have checklists and other guidance to ensure compliance with the manuals, CONOPS, and other factors that ensure mission success and minimize human error.

** d. We did include unknown winds aloft and unforecasted weather as hazards in our hazard analysis.

** e. We did include non-crew member interruption of flight crew in our waiver submission.

Form: UAS Operations – Part 1

UAS Operations - Part 1

Enter UAS Operations Information:

a. Operational procedures not defined and / or adhered to:

i. Within your ConOps, consider the consequences of operational procedures not defined, and / or adhered to. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

b. UAS collision with fixed obstacle:

i. Within your ConOps, consider the consequences of a UAS collision with a fixed obstacle. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

c. UAS collision / close proximity to another aircraft:

i. Within your ConOps, consider the consequences of a UAS collision / close proximity to another aircraft. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

d. Risk of premature launch:

i. Within your ConOps, consider the consequences of a premature launch. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

e. UAS not flying as expected:

i. Within your ConOps, consider the consequences of UAS not flying as expected. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

** We did include these items in our waiver submission; they are in our hazard analysis worksheets.

	Hazard Analysis Workbook Summary	Initial Risk	Residual Risk
1	Loss of UAS Command and Control Link	C3	C5
2	Loss of navigational control	E2	E2
3	Propulsion System Failure	C3	D3
4	sUAS Observer loses visual contact with UA	D2	E2
5	sUAS Fly Away	E2	E2
6	Lost comms between sUAS PIC and ATC	D5	D5
7	Lost comms between PIC and observers	C4	E4
8	Loss of Link with Tracking Antenna	B2	C4
9	Mid-Air Collision	E1	E1
10	Unknown Winds Aloft	B3	E3
11	Low or bingo battery prior to landing	E4	E4
12	Frequency Interference	D5	E5
13	Non-crew member interruption of flight crew	C3	D4
14	sUA collision with people inside takeoff/Landing area	E3	E3
15	sUA flight into pipeline	D3	E4
16	Unforecasted Weather	B5	B5
17	Loss of Data due to sUA fly away	D5	D5
18	Loss of Data due to sUA fly away	E1	E5

Form: UAS Operations – Part 2

UAS Operations - Part 2

Enter UAS Operations Information

f. Atmospheric disturbance-wind / wind shear:

i. Within your ConOps, consider the consequences of atmospheric disturbance, such as wind or wind shear. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

g. Flight beyond visual / radio line of sight:

i. Within your ConOps, consider the consequences of flight beyond the visual or radio line of sight. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

h. External supporting services to UAS are not consistent with ConOps indications. For instance, if certain weather forecast services are assumed to be provided, the external service does not provide weather forecast, or provides only partial information:

i. Within your ConOps, consider the consequences of external supporting services are not consistent with ConOps indications. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

i. No recovery from human error:

i. Within your ConOps, consider the consequences of a non-recovery from a human error. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of control of the aircraft?:

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

j. Undefined operational procedures in adverse conditions, or not adhered to:

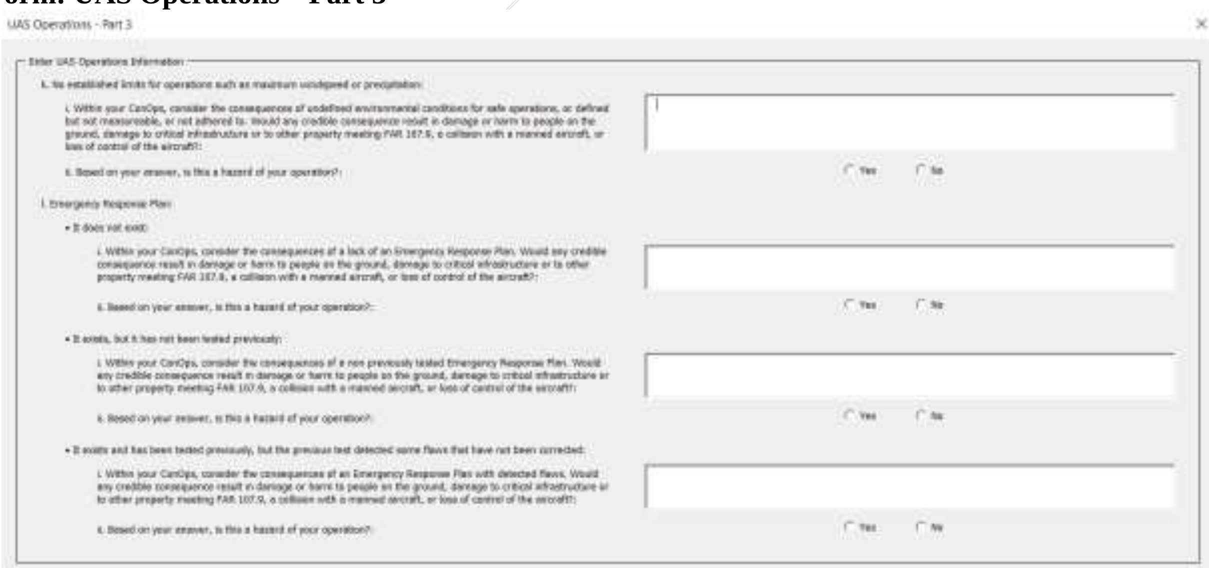
i. Within your ConOps, consider the consequences of undefined operational procedures in adverse conditions, or not adhered to. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAR 107.9, a collision with a manned aircraft, or loss of

ii. Based on your answer, is this a hazard of your operation?: ( ) Yes ( ) No

** We did include these items in our waiver submission; they are in our hazard analysis worksheets.

	Hazard Analysis Workbook Summary	Initial Risk	Residual Risk
1	Loss of UAS Command and Control Link	C3	C5
2	Loss of navigational control	E2	E2
3	Propulsion System Failure	C3	D3
4	sUAS Observer loses visual contact with UA	D2	E2
5	sUAS Fly Away	E2	E2
6	Lost comms between sUAS PIC and ATC	D5	D5
7	Lost comms between PIC and observers	C4	E4
8	Loss of Link with Tracking Antenna	B2	C4
9	Mid-Air Collision	E1	E1
10	Unknown Winds Aloft	B3	E3
11	Low or bingo battery prior to landing	E4	E4
12	Frequency Interference	D5	E5
13	Non-crew member interruption of flight crew	C3	D4
14	sUA collision with people inside takeoff/Landing area	E3	E3
15	sUA flight into pipeline	D3	E4
16	Unforecasted Weather	B5	B5
17	Loss of Data due to sUA fly away	D5	D5
18	Loss of Data due to sUA fly away	E1	E5

Form: UAS Operations – Part 3



** We have included unforecasted weather in our hazard analysis, which will include unexpected weather that has us exceed the max windspeed or precipitation allowed. We always have an emergency response plan, and we update it as we find weaknesses, so we did not include these in our waiver submission.