The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

UAS Test Data Collection and Analysis: Phase I Final Report

September 18, 2020

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16. Abstract

Execution of Unmanned Aircraft System (UAS) missions that are not permitted by existing regulations [e.g., 14 CFR (Code of Federal Regulations) Part 107] requires Federal Aviation Administration (FAA) approval of a safety case. While efforts are underway to establish standards that would eliminate the need for the safety case process, the variety of UAS missions and the pace at which standards are established result in safety case development being a common process that will enable UAS operations for many years to come. The characteristics of safety cases that are provided to the FAA, however, vary significantly. Consequently, a framework that supports safety case production and subsequent analysis is needed. By providing a safety-case framework, standardization of safety cases, to the extent possible, will support analysis of enablement of UAS missions—especially advanced operations, identification of research gaps, etc. Consequently, it will streamline UAS integration into the National Airspace System (NAS), supporting the goal of safe and efficient integration. This project focuses on establishment of a safety-case framework.

A safety case framework and an associated data schema were developed. This process involved reviewing existing best practices and multiple reviews. In addition, system software and hardware requirements were examined, a demonstration system was developed to elicit input from users regarding system efficacy, and training materials were developed.

These efforts set the stage for follow-on efforts that will be directed at developing a prototype data collection system (A19 Phase II), exercising the system, and developing an analysis system that can be used to understand progress associated with integrating UAS into the NAS—including identification of gaps and research needs. Thus, these results, combined with upcoming efforts, will streamline the safety case process, will support development of UAS research and development roadmaps, and will accelerate the safe and efficient integration of unmanned aircraft into the National Airspace System (NAS).

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Table of Acronyms

Acronym	Meaning
ADM	Aeronautical Decision Making
AIMS	Aviation Information Management System
ASSURE	Alliance for System Safety of UAS through Research Excellence)
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
BVLOS	Beyond Visual Line Of Sight
C2	Command and Control
CFR	Code of Federal Regulations
COA	Certificate of Authorization
CONOPS	Concept of Operations
DAA	Detect And Avoid
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FCS	Flight Control System
FHA	Functional Hazard Assessment
GCS	Ground Control System
HMI	Human Machine Interface
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IPP	Integration Pilot Program
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
JDOSAS	John D. Odegard School of Aerospace Sciences
KSN	Knowledge Services Network
LOS	Line Of Sight
MAAP	Mid-Atlantic Aviation Partnership
MLS	Mission Logging System
MSU	Mississippi State University
MTR	Military Training Routes
NAS	National Airspace System
NMSU	New Mexico State University
NPUASTS	Northern Plains UAS Test Site
NTIS	National Technical Information Service
OEM	Original Equipment Manufacturer
OOP	Operations Over People
ORA	Operational Risk Assessment
OTA	Other Transaction Agreement
PSP	Partnership for Safety Program
RPIC	Remote Pilot In Command
SFR	Special Flight Rules
SMS	Safety Management System
SORA	Specific Operations Risk Assessment
SRM	Safety Risk Management
sUA	small Unmanned Aircraft
sUAS	small Unmanned Aircraft System
TIM	Technical Interchange Meeting
UA	Unmanned Aircraft
UAF	University of Alaska Fairbanks
UAS	Unmanned Aircraft System
UASTS	Unmanned Aircraft System Test Site
UND	University of North Dakota
UTC	Universal Time Coordinated
UTM	Unmanned Traffic Management

VFR	Visual Flight Rules
VLOS	Visual Line Of Sight
VMC	Visual Meteorological Conditions
VO	Visual Observer

Executive Summary

Execution of Unmanned Aircraft System (UAS) missions that are not permitted by existing regulations [e.g., 14 CFR (Code of Federal Regulations) Part 107] requires Federal Aviation Administration (FAA) approval of a safety case. While efforts are underway to establish standards that would eliminate the need for the safety case process, the variety of UAS missions and the pace at which standards are established result in safety case development being a common process that will enable UAS operations for many years to come. However, the characteristics of safety cases that are provided to the FAA vary significantly. As illustrated by the FAA (2020), safety cases range from providing no information to providing detailed analysis and data regarding safety mitigations. Consequently, a framework that supports applicant safety case production and FAA analysis is needed.

Development of a safety-case framework also supports the mandate that the FAA develop a UAS research and development roadmap. By providing a safety-case framework, standardization of safety cases, to the extent possible, will support analysis of enablement of UAS missions—especially advanced operations [e.g., Beyond Visual Line Of Sight (BVLOS) operations], identification of research gaps, etc. Consequently, it will streamline UAS integration into the National Airspace System (NAS), thus supporting the goal of safe and efficient integration. This project focuses on establishment of a safety-case framework.

The high level objective of Phase I of the "A19_A11L.UAS.50 – UAS Test Data Collection and Analysis" project, referred to as A19 Phase I, is to develop a safety-case framework that supports UAS integration safety cases and is aligned with FAA functional areas, research domains, etc. The ASSURE (Alliance for System Safety of UAS through Research Excellence) A19 Phase I research team is comprised of the University of North Dakota (UND), the Northern Plains UAS Test Site (NPUASTS), the Virginia Tech Mid-Atlantic Aviation Partnership (MAAP), the University of Alaska Fairbanks (UAF) UAS Test Site, the New Mexico State University (NMSU) Unmanned Aircraft Flight Test Site, and Mississippi State University (MSU).

The ASSURE team developed a safety case and an associated data schema. This process involved reviewing existing best practices and multiple reviews. In addition, A19 researchers developed system software and hardware requirements, a demonstration system to elicit input from users regarding system efficacy, and associated training materials. It is noted that FAA reviews of the proposed system do not constitute an endorsement by the FAA.

These efforts set the stage for follow-on efforts that will be directed at developing a prototype data collection system (A19 Phase II), exercising the system, and developing an analysis system for collected data that can be used to understand progress associated with integrating UAS into the NAS—including identification of gaps and research needs. Thus, these results, combined with upcoming efforts, can streamline the safety case process, support development of UAS research and development roadmaps, and accelerate the safe and efficient integration of unmanned aircraft into the National Airspace System (NAS).

1 Introduction

Execution of Unmanned Aircraft System (UAS) missions that are not permitted by existing regulations [e.g., 14 CFR (Code of Federal Regulations) Part 107] requires Federal Aviation Administration (FAA) approval of a safety case. While efforts are underway to establish standards that would eliminate the need for the safety case process, the variety of UAS missions and the pace at which standards are established result in safety case development being a common process that will enable UAS operations for many years to come. However, the characteristics of safety cases that are provided to the FAA vary significantly. As illustrated by the FAA (2020), safety cases range from providing no information to providing detailed information, analysis, and data. Consequently, a system that supports applicant safety case production and FAA analysis is needed. This need can be understood in greater detail by considering the questions that define the scope of this effort.

1.1 Scope

The questions that define the scope of this effort are:

Question 1: What are the key test objective types that must be captured in an ideal UAS risk-based framework?

a. What are the current test objective types?
b. How are the objectives aligned with Safety Risk Management (SRM)/Safety Management System (SMS) practices?
c. How do the objectives fit in an integrated safety case framework?
d. How can these objectives be grouped in a logical manner?
e. How can novel test objectives be incorporated in any developed framework and mapped to existing flights and data?
f. How can the test objective types be aligned with FAA research needs and functional areas?

Question 2: What are the key test data that must be captured in an integrated safety case framework?

a. What are the key outputs/statistics needed for the FAA to evaluate UAS capabilities, failure modes, and the effectiveness of potential safety mitigation strategies?
b. How does the CONOPs and risk management objectives affect the type of data to be collected?
c. What is the minimum set of test data that captures enough specificity to answer technical questions but does not become too onerous to collect for the UAS operator?
d. How can proprietary data be collected and shared with the FAA more effectively?
e. How can proprietary information be secured but still accessible for analysis?
f. How can these data be shared, queried, and analyzed most effectively?

Question 3: How can the data collected by the FAA Test Sites inform a risk-based framework?

a. Of the suite of information that is currently being collected by the Test Sites, which data provides value for the FAA?
b. What information is not being collected by the Test Sites, but should be?
c. What are the current practices for data collection at the Test Sites?
d. What format/data definitions best serve a risk-based framework?
e. What are the economic and workload impacts of any proposed data collection changes on the Test Sites?

Question 4: What safety information is being collected by public and civil operators?

a. How do those data differ from what is being collected by the Test Sites?
b. Is the information that must be reported by these operators sufficient to build a safety case for these operations?
c. Does the FAA need to change the amount of data required from these operators to develop a robust safety-oriented data base?

1.2 Objectives

The overall objective is development of a test data collection and analysis system that:

- Enables production of safety cases that align with SRM/SMS practices
- Ensures collection of the proper types and amounts of data needed for safety case evaluation
- Minimizes, to the extent possible, the burden on users of the data collection system
- Supports analysis of collected data to inform integration of UAS into the National Airspace System (NAS), including identification of research gaps, evaluation of alignment with FAA research domains and functional areas, etc.
- Incorporates best practices

Given the broad scope, these objectives are being met through a series of research efforts. This 'arc' of research currently involves three separate research efforts:

- A11L.UAS.50 (Phase I) – UAS Test Data Collection and Analysis Phase I: The current research effort (A19 Phase I).
- A11L.UAS.50 (Phase II) – UAS Test Data Collection and Analysis Phase II: An immediate successor to A19 Phase I that involves an initial data collection system build (A19 Phase II).
- A11L.UAS.50: UAS Safety Case Development, Process Improvement, and Data Collection: A successor to A19 that continues to fulfill research objectives in this research arc (A24).

For this effort (A19 Phase I), the primary objectives are development of a safety-case framework and associated data schema. These provide the basis for a test data collection system, the prototype of which is to be built in A19 Phase II. Subsequently, a test data collection analysis system is to be added in A24. A24 also involves further development and testing of the overall system to enhance, where possible, system alignment with SMS practices, system utility for both the applicant and the FAA, and provision of solutions for all of the questions that define the scope of this research arc.

It is noted that users of the test data collection system are expected to be informed regarding production of safety cases, design and execution of tests, and SMS practices. While this does not preclude all users from utilizing the system, the support provided by both the system design/framework and system help should be supplemented to enable users who are new to this process to derive maximum benefit from the system.

The A19 Phase I research team is comprised of the University of North Dakota (UND), the Northern Plains UAS Test Site (NPUASTS), the Virginia Tech Mid-Atlantic Aviation Partnership (MAAP), the University of Alaska Fairbanks (UAF) UAS Test Site, the New Mexico State University (NMSU) Unmanned Aircraft Flight Test Site, and Mississippi State University (MSU).

1.3 Requirements

The defined requirements for the system are:

1. Provide a framework for developing/supporting UAS integration safety cases by utilizing test objectives and data.
2. Have the ability to 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, CVS, 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.

1.4 A19 Phase I Tasks

The A19 Phase I tasks are:

1. Develop safety-case framework: Develop an initial draft safety case framework for leveraging the FAA's test programs to collect test data that directly supports UAS integration safety cases while considering the constraints on these programs.
2. Develop data schema: Identify data elements needed to support integration safety cases that should be collected. The schema will align data elements within the safety case framework and to the FAA's research domains and functional areas.
3. 1st FAA review: Present results of tasks 1. and 2. and collect feedback.
4. 1st system revision: Revise the safety case framework and data schema based upon the 1st review.
5. 2nd FAA review: Present revised safety case framework and data schema and collect feedback.
6. 2nd system revision: Revise the safety case framework and data schema based upon the 2nd review.
7. Examination of software and hardware requirements: Examine existing software and hardware solutions to identify best options, including development of a new solution.
8. Develop demonstration system: Develop a demonstration reporting system for evaluation of concepts.
9. Develop training materials: Develop materials to help the user understand system philosophy, design, user interface, and features.
10. Final report: Final report and briefing.

The following describes how these tasks were completed.

2 Safety-Case Framework

2.1 Introduction

Task 1 requires that an initial safety-case framework be developed for leveraging the FAA's UAS test programs, such as the UAS Test Sites, UAS Integration Pilot Program (IPP), and UAS Partnership for Safety Programs (PSPs). The basic framework utilized at the starting point of this task was a four-phase safety case development process created by the Virginia Tech MAAP shown in Figure 1. MAAP formulated this process through multiple iterations with commercial partners and FAA stakeholders while pursuing 14 CFR Part 107 waivers. The process allows for the flow of contextual information from the starting point in Phase 1 all the way through to FAA approval and identifies the necessary data collection elements required to support a safety case.

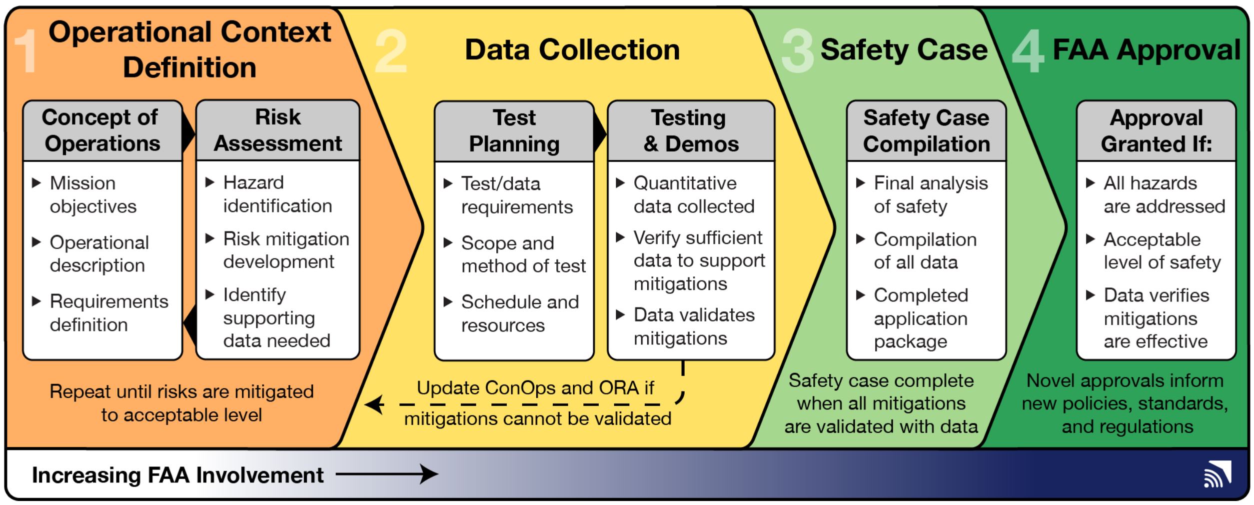


Figure 1: Virginia Tech MAAP Safety Case Development Process.

The remainder of this section expands on each phase of the safety-case framework to understand the data required to get to Phase 4. The goal of this Task 1 deliverable is to characterize the framework with enough fidelity to inform *Task 2: Develop Data Schema* such that a draft framework and data schema can be provided to the FAA for their initial review.

2.2 Approach

The approach taken to understand the data for each phase of the framework consists of three primary factors: 1) identify the sources of data, 2) describe the data components of each phase, and 3) define the context for each phase of the framework. The research team provides an explanation of each factor in this section. Additionally, they present the drivers that initiate the safety-case framework in this document, along with environmental outcomes that impact UAS regulation and the broader UAS industry upon successful completion of the process.

2.2.1 Identify the Sources of Data

Data are needed to validate risk mitigations to enable approval of a safety case. These data can come from a variety of sources, and can be existing or may be derived as part of development of a safety case. There are three primary options here: 1) data that are provided by industry (likely as an input), 2) data derived during the process, and 3) data that originates from a third party (either prior to or during the process).

Different sources of data and potential utilization of proprietary information create significate challenges for providing a common data format. Different data sources may also come with varying degrees of credibility or trust that must be considered when determining the robustness of data needed to support the completed safety case. Specifically, credibility may need to be assessed for data that are raw and unfiltered, or have been post processed or filtered before being provided.

2.2.2 Describe the Data Components of Each Phase

The data components of each phase consist of data elements, data types and formats, and data collection methods. Describing these components represents the primary goal of this project to identify the data that will be collected and how they are collected. However, this information (elements, types, formats, and collection methods) cannot be determined without consideration of data sources and context within the framework.

The approach for this factor was to identify representative data elements, types, formats, and collection methods, but not to identify a comprehensive list of such components. A near-infinite number of possible data components could be listed, depending upon the question under investigation. Therefore, it is proposed that no complete list of data components can be defined, but instead the process should be utilized to identify, define, and collect the proper data for the question at hand.

2.2.3 Define the Context for Each Phase of the Framework

The FAA also requested that the ASSURE project team develop a framework that considers the context of 1) safety case tools, 2) compatibility with FAA research and functional areas, 3) test program constraints, and 4) features of reporting systems. Therefore, this report addresses these items for each phase of the safety-development process.

2.3 Industry Drivers

The safety-case framework for data collection must have a starting point and this is typically driven by the commercial UAS industry that seeks to gain a new capability. There is no reason to develop a safety case if there is not an industry driver that spurs the need for expanded operational or technical capability. Therefore, the primary industry input is a business need or driver that initiates the process.

The research team identified three primary business drivers that can be considered inputs to the process: 1) expanded operational capability beyond existing regulations (e.g. Part 107 waivers, 44807 exemptions), 2) technology that must be proven to comply with existing regulations (e.g., aircraft certification), and 3) a specific type of operation that must be shown to comply with existing regulations (e.g., Part 135 certification). Notably, these business drivers can each stand on their own or they can be combined with each other. Industry inputs that drive the initiation of a safety case must be considered throughout every step of the process. They are the purpose for the entire undertaking and if the process does not result in the realization of these objectives, then the effort will be of little to no benefit.

Best Practice: Bounding the Operation
A best practice identified by the Virginia Tech team is to have the industry partner describe their desired optimal result from the process along with their “minimum viable product”. This sets thresholds for where the safety case must stay “in bounds” and prevents risk mitigations from being set which would result in an unfeasible business case.

It is noted that Best Practices and Reporting System Recommendations that are provided throughout the description of the safety-case framework are collected in Appendix A for convenience.

2.4 Phase 1: Operational Context Definition

2.4.1 Description

The first phase in the safety case development is definition of the operational context (Figure 2). This phase is crucial to laying the groundwork for subsequent phases by providing traceability for data collection from the original mission objective all the way through to the final safety case. The operational context definition phase begins with the development of a Concept of Operations (CONOPS) to identify and describe, in detail, all of the different aspects of the operation. The CONOPS includes, but is not limited to, such items as the following:

- Purpose of the operation
- System description
- Crew member qualifications and training
- Operational scenario description
- Operational considerations – ground based and airspace
- Meteorological conditions
- Time of operations
- Communications
- Safety and security
- Situational awareness tools
- Abnormal procedures
- Accident reporting procedures

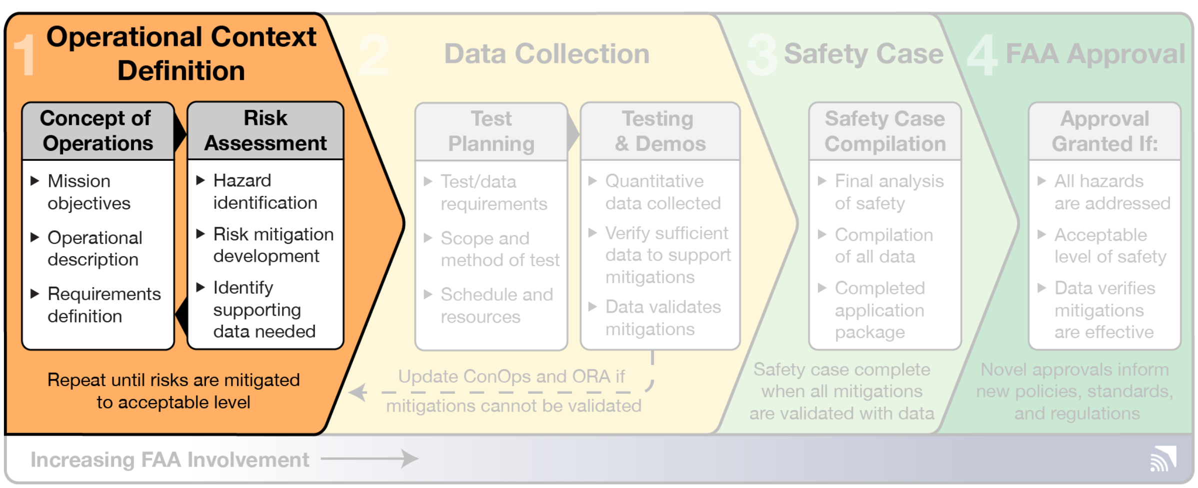


Figure 2: Phase 1 – Operational Context Definition.

The details of the CONOPS are then utilized to draft the Operational Risk Assessment (ORA), which identifies the primary hazards and associated risks. Risk mitigations are then developed to reduce the overall risk to an acceptable level. The output of the ORA is an assessment of residual risk once all risk mitigations are implemented. Risk mitigations that impact the CONOPS are then utilized to update the CONOPS and the ORA process is subsequently repeated. This results in an iterative development process for a CONOPS and ORA until all risks have been mitigated to an acceptable risk level in the assessment.

It is noted that this is one of the most critical steps in safety case development. Safety cases commonly fail owing to not identifying all relevant risks (and thus not mitigating them) and insufficient testing (e.g., FAA 2020). The ORA/SRM step must be robust in terms of hazard identification and development of mitigations. Guidance regarding SMS and ORA/SRM are provided, for example, by U.S. Department of Transportation (2017; 2019; 2020).

During the CONOPS and ORA iterative process, supporting data for proposed risk mitigations are collected to strengthen the assessment of risk reduction. These data could be quantitative (preferred) or qualitative. The iterative process is complete when the risks have been mitigated and all available supporting data have been identified. The final portion of this phase is to identify which risks require the collection of additional supporting data to be validated.

Best Practice: Narrowing the Context
Starting the CONOPS and ORA iterative process with a very general CONOPS with only the major desired structural elements ensures that potential risk mitigations are not overlooked. If the process is started with a rather detailed CONOPS, then it is possible that some mitigations are preempted by the selection of technology or operational limitations that preclude other alternatives. The end result, enabled through iteration of Phases 1 and 2, is a description of a general CONOPS and of specific use cases or CONOPS that capture details of the specific operation(s) of interest.

Best Practice: Prioritizing Risk Mitigations
It is advantageous to prioritize risk mitigations early in the process. It may be that many risk mitigations that improve safety can be identified, but not all are critical-path risk mitigations. Critical-path risk mitigations are ones that substantially impact the residual risk of the operation and likely require the most supporting data to validate. An analog to this would be the “robustness” described in the JARUS SORA (Joint Authorities for Rulemaking on Unmanned Systems Specific Operations Risk Assessment; JARUS 2019) documents.

2.4.2 Data Sources

As the starting phase of the safety-case framework, Phase 1 relies more heavily on external data sources as inputs to the process than subsequent phases. The industry driver that initiates the process serves as a major input data source and other best practices are drawn from the completion of prior work in the industry (Table 1).

Table 1: Industry provided data sources for Phase 1.

Industry Provided Data Sources	
Mission Objectives	Industry provides the desired objective for the operations that will ultimately be realized with a new approval.
Technology Specifications (optional)	Technology may be provided as an input, but this is not always the case, especially when the industry driver is an end user of some data provided by the operation. Technology inputs may include specific UA (Unmanned Aircraft) systems or subsystems [aircraft, DAA (Detect And Avoid) sensors, etc.].
Desired Operations Versus Minimum Viable Operations	The industry should define the desired operation and also outline the minimum thresholds of approval that would be acceptable for their business case.

The iterative CONOPS/ORA development process will also derive certain data elements and thus the process itself becomes a source of data. Table 2 lists some examples of process-derived data, but is not intended to be a comprehensive list.

Table 2: Process derived data sources for Phase 1.

Process Derived Data Sources	
Complete Operational Description	A complete operational description is developed as risk mitigations are imposed through the ORA and are implemented into the CONOPS during the iterative process of operational context definition.
Crew Training	Training is often used as a risk mitigation and, therefore, the requirements for crew training are developed over the course of Phase 1.
Technology Requirements	Risk mitigations that rely on technology (versus procedural, operational, or training mitigations) should describe the requirements for the technology to achieve the assessed risk reduction.
Operational and Technological Limitations	Each system has limitations and every operation has bounds. These are identified to ensure proper system and operational performance, and are commonly captured as part of the CONOPS and/or as assumptions for the ORA.
+More	There are likely additional data elements that are process derived during Phase 1.

Third party data sources (Table 3) can provide a substantial dataset for Phase 1, especially from groups that have already completed similar operations.

Table 3: Third party data sources for Phase 1.

Third Party Data Sources	
Industry Standards	Industry standards can provide a wealth of information that informs CONOPS and ORA development. A major benefit of industry standards is their rigorous development process that includes input from many stakeholder perspectives.
Standardized Scenarios	Standardized scenarios are developed from common themes in operational scenarios that demonstrate best practices and operations for the specific scenario. JARUS and ASTM (American Society for Testing and Materials) have both begun developing standardized scenarios for common use cases that provide great data sources to inform Phase 1.
Published Research	Published research data can be utilized to determine possible risk mitigations, technology effectiveness, best practices, and many other elements of the CONOPS and ORA. Peer reviewed research publications can also provide great supporting data for risk mitigations.

2.4.3 Data Components

The data components for Phase 1 are primarily narrative documents and spreadsheets that describe the operation and assess risk (Table 4). Certain elements contained in these narrative documents might be extractable into a database system. However, this will require either a standardized format that may not capture the intricacies of the various use cases or a duplication of data into a format that can be easily queried and reported.

Table 4: Phase 1 Data Components.

Phase 1 Data Components	
Data Elements	CONOPS documents (baseline and final): • System description • Crew qualifications and training • Operating environment • Procedures, etc. ORA documents (baseline and final): • Identified hazards (potential harm) • Risk assessment (hazard severity and likelihood) • Risk mitigations (priority + supporting data) • Residual risk assessment (post-mitigation)
Collection Methods	Submitted documents Standardized scenarios
Data Formats	Narrative text documents (may contain graphical data) Spreadsheets Database files Other

2.4.4 Context Considerations

2.4.4.1 Enable Supporting Safety Case Tools

Phase 1 enables safety case tools naturally by leveraging an iterative CONOPS and ORA process that must identify and evaluate all possible hazards that may occur during the operation. The exact tools that are utilized may vary across programs, but common tools such as a Functional Hazard Assessment (FHA) are useful in developing a well-supported ORA document.

2.4.4.2 Ensure Compatibility with FAA Research and Functional Areas

Phase 1 leverages the FAA's research and functional areas through an early engagement during the process to determine feasibility and seek feedback regarding the intended operation. Compatibility with the appropriate FAA research and functional areas are ensured during this early phase of the safety case development process.

2.4.4.3 Consider Test Program Constraints

Since Phase 1 does not require flight operations, very few constraints are placed on this phase. The primary constraint is availability of funding to conduct the work, which would likely be provided by an industry sponsor, but there are no known legal restrictions on funding sources for this phase. A potential constraint is the ability of the various test programs to lead the development of an effective CONOPS and ORA through this iterative process. Detailed guidance on how to develop an acceptable CONOPS/ORA is needed to ensure consistency across the test programs. It is noted that ASTM F38 has published an ORA standard (ASTM 2017) that captures much of this needed guidance, but likely not all.

2.4.4.4 Consider Features of a Reporting System

Data formats traditionally utilized for this phase are primarily narrative. This makes capturing the data into a reporting system challenging. As mentioned above, either a standardized format for narrative documents or duplication of data into an easily reportable format is needed. However, standardization of these narrative documents could fail to capture the unique details from the innumerable potential use cases.

Reporting System Recommendations:

- Identify data fields from the CONOPS/ORA that could be standardized across the industry and submitted in a reportable format
- Consider how a standardized format could be utilized to enable greatest data collection efficiency
- Consider how data could be categorized most effectively if it cannot be broken into discrete data fields
    - Operation type [BVLOS (Beyond Visual Line Of Sight, OOP (Operations Over People), etc.]
    - Mitigation type
    - UAS type
    - Airspace type

2.5 Phase 2: Data Collection

2.5.1 Description

The data collection phase (Phase 2; Figure 3) of the safety-case framework is the intensive data production portion of the process where new data are generated and collected to answer specific questions. Historically, the subtasks contained within Phase 2 have often been viewed as the entirety of all data collection for UAS test programs; however, under the safety-case framework proposed here, the data collection phase cannot exist or be relevant without the first phase that defines the operational context. Phase 1 generates the questions that must be answered in Phase 2, which are typically centered on providing data to validate the effectiveness of the risk mitigations developed during the CONOPS/ORA iterative cycle.

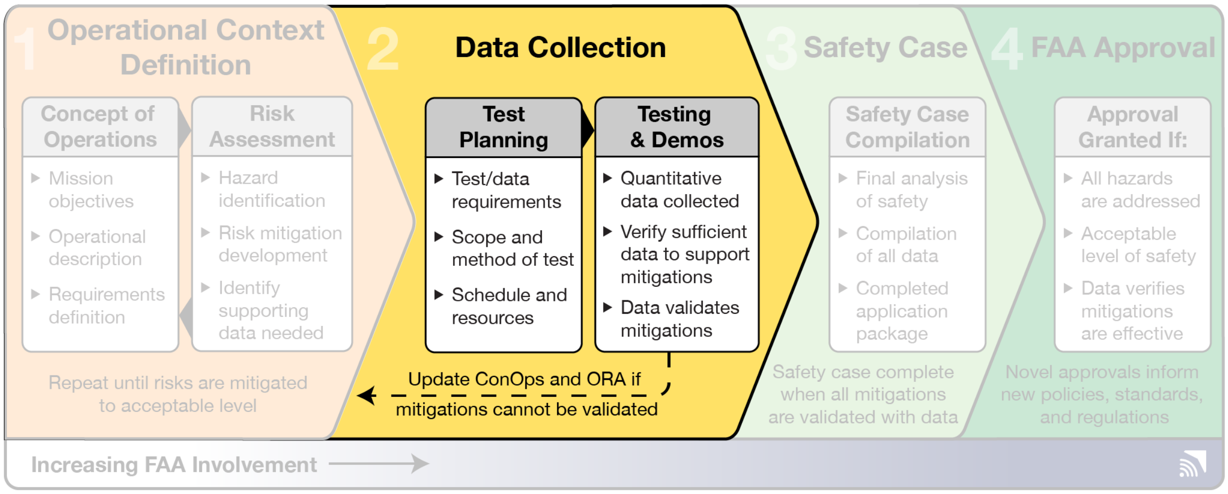


Figure 3: Phase 2 – Data Collection.

The outputs of Phase 1 are identified risk mitigations and the supporting data needed to validate them. The first task under Phase 2 is to plan tests that provide the needed supporting data. The planning of tests can be quite intensive, as it requires a methodical development of test requirements and scope that will deliver adequate data to support the validation of the risk mitigations. The level of robustness is determined by the criticality of the risk mitigation, input from the FAA and other subject matter experts, and industry best practices/guidance. A completed test plan should clearly identify the test article(s), test parameters, method, data to be collected, success criteria, etc. The test planning task also should identify the schedule for testing, any prerequisite tests or order of testing, and the types of resources needed to effectively execute the tests. Test cards, while not a regulatory requirement, are invariably needed to provide test participants with only the specific information they need to conduct a test and effectively capture data. Thus, test cards are generally required for this phase.

The second task in Phase 2 is to conduct tests in accordance with the test plans and collect the predefined data required by the plan. The types of data collected during this phase are limitless because the data collected should be designed to validate a limitless number/type of risk mitigations that might be proposed during Phase 1. It is not possible to characterize all possible data that could be utilized to validate risk mitigations. However, it is possible to characterize the method for identifying the appropriate data collection parameters. The simple characterization of this method is that the data collected during testing should be the data that provides sufficient evidence that the proposed risk mitigation is valid and reduces risk as assessed in the ORA. “Sufficient evidence” is based upon the criticality of the risk mitigation and desired robustness of the supporting data to meet the target level of safety assurance.

Test reports should be completed for each defined test that analyze the raw test data to provide the results of the tests and determine if the data collected successfully validate the risk mitigations. Raw test data without traceability from the risk mitigation through the test plan and to the final test report often does not contain enough context to be useful for the safety case process or for future regulatory/policy decisions that are potential outcomes from the complete safety-case framework. If test results do not validate the risk mitigation, then it is necessary to reassess the CONOPS and ORA to determine if additional or alternate risk mitigations are needed to conduct the operation safely.

Best Practice: Identify Success Criteria Early
A properly prepared test plan will identify the success criteria clearly. This will enable the individuals conducting the tests to determine, during the course of testing, whether or not success is likely. If a test appears to be clearly failing the success criteria, it may be beneficial to discontinue the test and save resources while the operational context is updated and new risk mitigations are proposed.

2.5.2 Data Sources

Data sources for Phase 2 are inherently more process derived than they are external. The external data sources should have been heavily used to inform the validity of risk mitigations prior to testing and the data that remain to be collected are those that do not already exist or are not accessible. However, there are some areas where external data can be utilized to inform the data collection phase (Table 5).

Table 5: Industry provided data sources for Phase 2.

	Industry Provided Data Sources
Industry Research and Development	Industry partners may be able to provide data that support risk mitigations from their own internal testing. These data can be existing data that were produced prior to the safety case process or industry partners can perform their own testing based upon the proposed risk mitigations. This may take the form of subsystem testing performed for a specific technology provided by an industry partner that supports the larger system that is being utilized in the safety case.
Industry Operational Data	Operational data provided by industry may be a source of data that can be utilized to validate risk mitigations through operational history. However, historical operational data must be carefully examined to understand if the context of the operational data accurately reflects the proposed CONOPS.

The primary purpose of Phase 2 is to collect data through the safety-case process to validate the proposed risk mitigations. Therefore, the data source for much of this phase is typically process derived, meaning it has been identified and collected as a part of this specific process. Table 6 lists the process derived data sources for Phase 2. It is noted that test reports serve numerous functions, as delineated in Table 6.

Table 6: Process derived data sources for Phase 2.

	Process Derived Data Sources
Test Plans	Test plans establish the who, what, why, when, where, and how the system will be tested. Each of these items is a relevant data source to the overall safety case.
Test Cards (optional)	Test cards provide an abbreviated summary of the test conditions and method of test that enable effective test conduct in the field.
Raw Test Data	Raw test data can take innumerable forms, but this is the source of data that lays the building blocks for the successful validation of risk mitigations.
Test Reports	Test reports provide analysis of the test results and characterize the test as successful or unsuccessful. Test reports should: • Interpret results to support the safety case

	• Show traceability to requirements developed in the ORA (Phase 1) • Validate the system and proposed operation • Validate that system and operational limitations/bounds are well understood

Third party data sources (Table 7) can help standardize testing for various topics and also provide relevant comparable data points from other tests.

Table 7: Third party data sources for Phase 2.

Third Party Data Sources	
Industry Standards	Industry standards that define tests, such as ASTM's parachute standards (ASTM 2018), can be utilized in their entirety to validate certain risk mitigations. However, their applicability must be determined during the test planning phase and not after completion of testing. Any deviations from an accepted industry standard should be noted and the impact of the deviation should be analyzed and presented within the test report.
Published Research	Published research can provide an effective corroboratory source of information for tests conducted during Phase 2. It can also be utilized to understand appropriate test parameters during test planning.

2.5.3 Data Components

As detailed in the description of this phase, the data components for Phase 2 (Table 8) are limitless because the data that are collected are utilized to validate a limitless number of potential risk mitigations. The basic data elements of Phase 2 are the test plans, test cards, raw test data, and test reports identified in the data sources above. However, instead of attempting to identify all possible data types, collection methods, and formats, the research team proposes that the method of identifying these components be established as work continues on the framework.

Table 8: Phase 2 Data Components.

Phase 2 Data Components	
Data Elements	Test Plans • Who, what, when, where, why, and how • Data identified that will validate the effectiveness of the risk mitigation • Method of test • Test conditions/parameters • Success Criteria Test Cards • Test conditions/parameters • Test execution notes • Data collection process Raw Test Data • Data captured during testing Test Reports • Data analyzed to determine if success criteria were achieved • Effectiveness of risk mitigation compared to assumed or calculated effectiveness in ORA document
Collection Methods	Appropriate to the type of data being collected
Data Formats	Narrative text documents (may contain graphical data) Spreadsheets Database files Imagery Flight logs Other

2.5.4 Context Considerations

2.5.4.1 Enable Supporting Safety Case Tools

Phase 2 enables safety case tools by leveraging the work completed in Phase 1 to inform the testing and data collection required in Phase 2. Safety case tools will carry through the data collection phase to provide traceability for why certain tests were conducted and how they prove the validity of proposed risk mitigations.

2.5.4.2 Ensure Compatibility with FAA Research and Functional Areas

Phase 2 will provide data to support the FAA's research and functional areas by conducting testing that informs areas where there is not enough existing supporting data already available. The data provided during this phase are inherently relevant because they are addressing risk mitigations that are not supported by existing data.

2.5.4.3 Consider Test Program Constraints

Phase 2 likely involves significant flight operations, along with potential ground testing components. The introduction of flight operations into the process places significant potential constraints upon the test programs that are currently in place for UAS testing. Specifically, the UAS Test Sites have historically conducted most of their testing as public aircraft. Public aircraft operations require that the flights be conducted for specific purposes (i.e., aeronautical research) and not for compensation or hire. Since the purpose of this flight testing is to validate risk mitigations that are associated with aeronautical operations, this purpose limitation can likely be met, but the flights cannot be conducted for compensation. This limitation significantly constrains the funding sources for the data collection phase.

In addition to funding source limitations for public aircraft operations, the tests that are designed to validate risk mitigations may fall outside of existing operational authority, such as Part 107. This necessitates that test operations may require public aircraft operations with an appropriate COA (Certificate of Authorization), a Section 44807 exemption, or a waiver to existing operational rules be in place before the tests are conducted. Since the purpose of this entire process is to build a safety case for such approvals, this means that iterative safety cases may be necessary for certain operational approvals to authorize flight tests to validate risk mitigations.

2.5.4.4 Consider Features of a Reporting System

The preceding sections describe how the data types that may be collected during Phase 2 are limitless and, therefore, that it is not possible to define every potential feature of a reporting system. However, it is likely possible to characterize general groups of data that might be provided during a typical data collection phase and use this characterization to establish a baseline for data reporting. It is extremely important that any such data reporting system allow for flexibility to capture data that were not anticipated during the creation of the reporting system. The need for flexibility may reduce over time as datasets become well defined for various applications, but an open-ended system is needed at the outset and likely into the foreseeable future.

Reporting System Recommendations:

- Identify as many possible types and formats of data that might be collected during a test data collection phase based on historical and expected testing
- Allow open-ended additions of alternate types of datasets that were not foreseen during the development of the reporting system
- Consider how effectively test data could be standardized for certain common types of testing
- Consider how data could be categorized if they cannot be discretely identified
- Consider weighting information (required, desired, optional, etc.) or recommending a minimum subset

2.6 Phase 3: Safety Case

2.6.1 Description

Phase 3 of the safety-case framework is development of the safety case based upon the prior operational context and data collection phases (Figure 4). To reach this phase, the proposed risk mitigations must have each individually been validated through existing or newly collected supporting data. Phase 3 is where the collective risk is assessed based upon all supporting documentation, the operational context is finalized, and all supporting documents are compiled into a single package that can be submitted to the FAA for review.

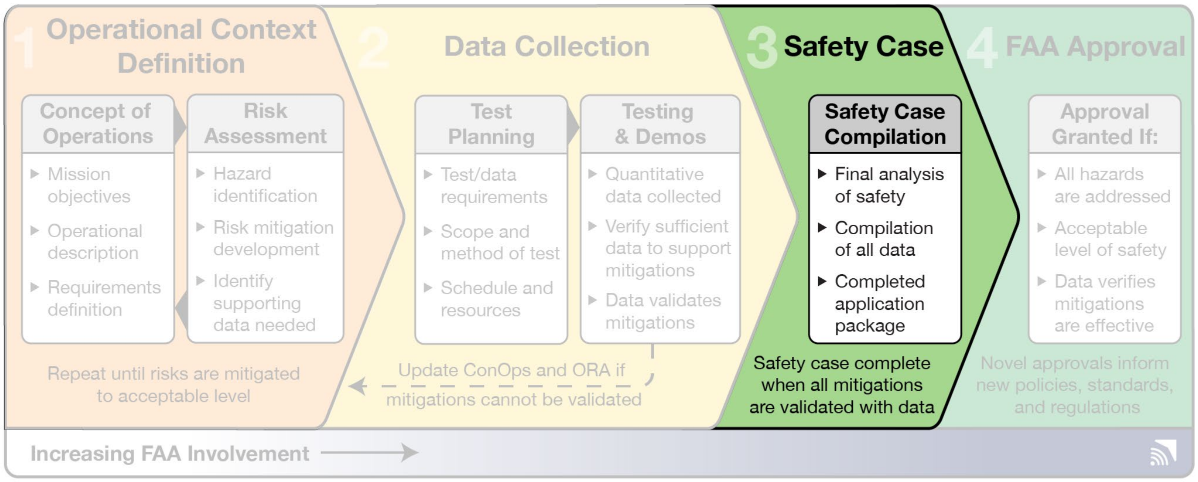


Figure 4: Phase 3 – Safety Case.

The final determination of risk and subsequent level of safety should now be supported by quantitative data that is commensurate with the initial and residual risk of the operation, along with the criticality of the implemented risk mitigations. FAA involvement is important throughout the process, but is especially valuable as the safety case is finalized to ensure that there are no existing areas of concern. The final safety case can be submitted to the FAA for review when all documentation is complete, to include any relevant manuals, training curricula, and operational procedures.

Best Practice: Agree On Expected Outcomes
As the safety case is finalized, the outcomes (e.g., residual risk) supported by the data should be presented. It is important that outcomes supported by the documentation align with the FAA's expectations. Therefore, it is important that desired outcomes be identified early in the process (Phase 1) and that the finding in Phase 3 agrees with those desired outcomes.

Best Practice: Organization of Safety Case Matters
Safety cases that are developed for complex operations can be extremely lengthy. It is important that the information be organized in a fashion that is easy to follow, summarizes the findings, and also provides clear direction on where to look for the details. A concise and organized safety case will be easier for FAA reviewers to navigate and identify the needed information, and will have a higher probability of a successful review.

2.6.2 Data Sources

Data sources for Phase 3 are typically entirely process-derived sources that were developed during the previous phases of the safety case process.

2.6.3 Data Components

The data components for Phase 3 are primarily narrative documents with supplements (e.g., appendices) that may include quantitative or graphical data. The basic data components of this phase are outlined in Table 9.

Table 9: Phase 3 Data Components.

Phase 3 Data Components	

Data Elements	Narrative Safety Case Summary
	• Summary of CONOPS, ORA, testing, and results
	• Final analysis of level of safety
	• Description of where to find further information in supporting documents
	Appendices/Attachments
	• Final CONOPS
	  ○ System information/specifications/limitations
	  ○ Procedures
	  ○ Assumptions (e.g., standards utilized)
	  ○ Etc.
	• Final ORA
	• Test Plans
	• Test Reports
	• Raw Test Data (as appropriate)
	• Manuals
	• Training Curricula (if needed)

Collection Methods	Submitted documents
Data Formats	Narrative text documents (may contain graphical data) Spreadsheets Database files Imagery Flight logs Slides Other

2.6.4 Context Considerations

2.6.4.1 Enable Supporting Safety Case Tools

Phase 3 enables safety case tools by providing traceability for the entire safety case process from the beginning to the end, which includes the use of safety case tools.

2.6.4.2 Ensure Compatibility with FAA Research and Functional Areas

The final safety case documentation should provide a clear and logical explanation of the work completed during the process that can inform FAA research and functional areas.

2.6.4.3 Consider Test Program Constraints

The primary constraint associated with Phase 3 is the capability of the individual test programs to perform the necessary analysis of the level of safety and to convey that information clearly in a format that is easy for reviewers to understand. There are no limitations on funding sources or operations associated with this phase.

2.6.4.4 Consider Features of a Reporting System

Since Phase 3 is a compilation of the results from prior phases, most of the reporting should already be complete. However, the "whole picture" provided by the final safety case is valuable for understanding how all the pieces fit together. For this reason, it is recommended that the reporting system include some method of submitting the summary narrative of the safety case and categorizing it according to the type of operation.

Reporting System Recommendations:

- Provide a means to summarize the findings of the safety case package without creating duplicate writing requirements
- Consider ways to standardize safety-case format so that it could be broadly applicable across many different use cases and operational types
- Consider categorizing safety cases based on common elements

2.7 Phase 4: FAA Approval

2.7.1 Description

The final phase of the safety-case framework (Figure 5) is initiated when the safety case is submitted to the FAA for review. Since this phase occurs outside of the test programs, a detailed characterization of this phase is not included in this framework. However, it should be noted that the FAA should grant approval of the proposed operation if the hazards have been adequately addressed through risk mitigations that are supported by data and both the applicant and the FAA determine that an acceptable level of safety has been reached. If there are discrepancies between the determinations of the level of safety by the FAA versus the applicant, then detailed feedback should be provided to the applicant so that any differences can be reconciled.

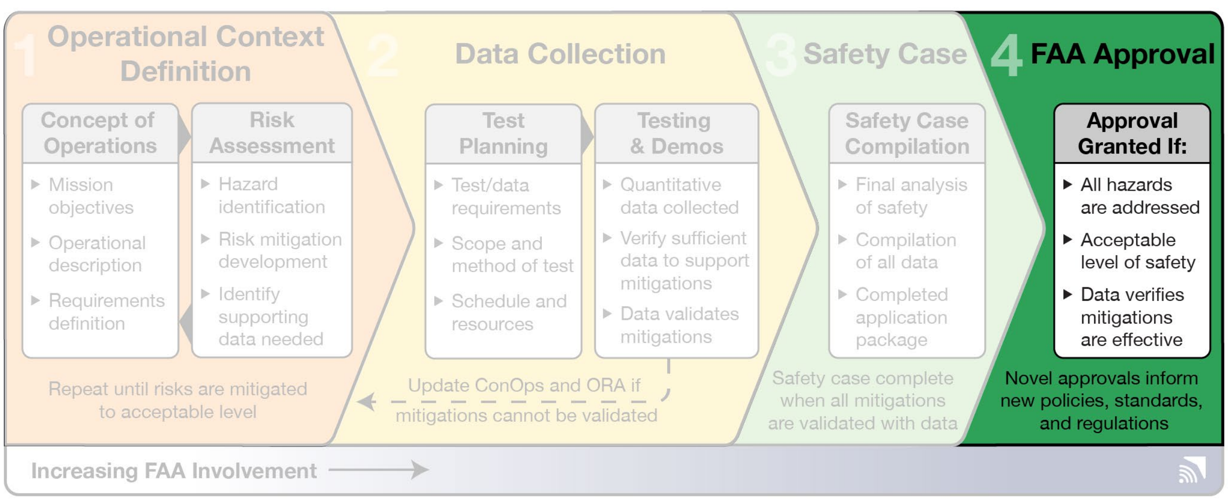


Figure 5: Phase 4 – FAA Approval.

Best Practice: Post-Submission Meetings
Safety cases for complex operations that are submitted to the FAA can greatly benefit from a meeting between the applicant and the FAA to explain in detail the operation that is requested, information that is being provided and how to navigate it, and to answer any questions from FAA reviewers. This informational meeting can greatly reduce the misunderstandings that may arise when trying to navigate lengthy documents.

2.8 Environmental Outcomes

The safety-case framework for data collection presented here has numerous potential environmental outcomes that further the UAS industry and integration of UAS into the NAS. Specifically, the direct outcomes from a successful safety case include new approvals, which may contain proprietary data, in the form of waivers, exemptions, aircraft certifications, etc. Indirect outcomes provided by this framework include the collection of new data to support regulations, policies, guidance, standards, and best practices for UAS, the enabling of new markets (e.g., Urban Air Mobility), and an overall reduction in risk that may be achieved by performing some missions with UAS technology.

Best Practice: Informing the Industry
Test programs that follow this safety-case framework should actively seek ways to share their lessons learned and associated data with the UAS industry. Industry consensus standards groups such as ASTM and RTCA offer ripe opportunities for the test programs to share what they have learned with the broader community, even if they must limit the release of proprietary data. Sharing of lessons learned, within the constraint of protecting proprietary data/information, enables development of standards that serve both test programs and industry.

2.9 Conclusion

The above described safety-case framework provides a logical flow from an industry driver (i.e., business case) through a process that encourages traceability of data, and the associated context of those data, to a completed safety case that can inform FAA decision making on numerous fronts. It should be noted that this task within the test data collection project does not attempt to define all possible data elements that might be collected in a test program, but instead focuses on establishing a repeatable framework and associated methods to determine the appropriate data that should be collected from relevant test programs. Subsequent tasks within this project will define a data collection and reporting system with greater fidelity to identify the data schema that is appropriate for this framework.

3 Data Schema

Arguably, design of a data schema is the most challenging aspect of this overall effort. The following subsections describe the data schema, which is the result of numerous interactions and two formal FAA reviews. This schema aligns with the Safety-Case Framework developed in the previous section. It is noted that data provided during Phase 1a (CONOPS) could be leveraged to pre-populate fields later in the process. This opportunity will be explored as the system is built-out and tested.

3.1 Phase 1a: Concept of Operations

Table 10 provides the data schema for Phase 1a—Concept of Operations. This is divided into the following subsections:

- Metadata
- System Information

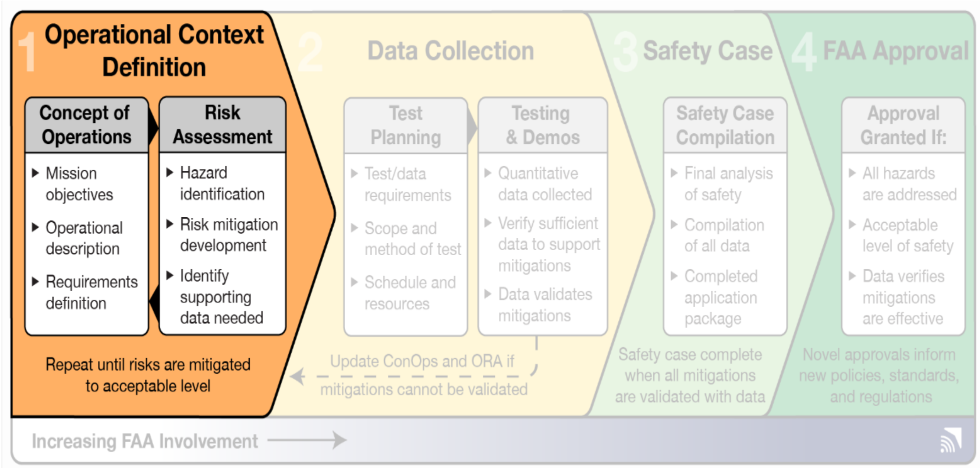
- Aircraft Procedures
- Crew Members
- Operational Scenario Description
- Operational Considerations—Ground Based
- Operational Considerations—Airspace
- Meteorological Conditions
- Communications
- Security

Information provided includes:

- A description of the CONOPS phase
- Data fields
- Data types
- Suggested input methods
- Input characteristics (e.g., units, data format)
- Relationships to other phases
- Descriptions of subsections, fields, etc.

Table 10: Data schema for Phase 1a—Concept of Operations.

<table>
<tr><th colspan="5">PHASE OF PROCESS</th><th>DESCRIPTION OF DATA SCHEMA</th></tr>
<tr><td colspan="5">



</td><td>The CONOPS is one of the few areas in the safety-case framework where much of the details about the operation can be predefined in set fields. The data fields identified here are not intended to be all inclusive at this point, nor should all fields be mandatory for any specific operation.

In the safety-case framework, the CONOPS and ORA are meant to be developed in an iterative process. This iteration may continue through until the final safety case is complete. Therefore, it may be helpful to have a method to enter an initial CONOPS early in the project and then a final CONOPS at the end that contains updates from what was learned during the testing phase.</td></tr>
<tr><th colspan="6">METADATA</th></tr>
<tr><th>Field</th><th>Data Type</th><th>Input Method</th><th>Input Options</th><th>Relationships</th><th>Description/Notes</th></tr>
<tr><td>Project Identifier</td><td>Text</td><td>Manual entry</td><td>Custom</td><td>Carried across all</td><td>Allow for custom identification of projects, however, it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.</td></tr>
<tr><td>Title of Project</td><td>Text</td><td>Manual entry</td><td>Custom</td><td>Carried across all</td><td>Allow users to custom name their projects for easy reference.</td></tr>
</table>

User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.
Keywords	Text	Manual entry Radial buttons	Custom Predefined	Some may be carried from other phases	Keywords may include any number of relevant words. This can be used to identify unique aspects of the CONOPS. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.

SYSTEM INFORMATION

Field	Data Type	Input Method	Input Options	Relationships	Description
Aircraft Picture	Image	Upload	JPG PNG TIFF	Carried forward to other phases to inform standard system configuration.	The system information should provide enough detail to characterize all relevant aspects of the system. Pictures and drawings are extremely useful for understanding configuration of the system. Therefore, there may be pictures or drawings provided for multiple aspects of the system, such as: airframe, propulsion unit, payload, control station, etc. It is important that the system information describe the system as it will be configured in normal operation, versus a special configuration that might be necessary for testing. The differences between normal configuration and test configurations
Type	Text	Drop down list	Fixed wing Helicopter Multirotor Hybrid		
Max Takeoff Weight	Text	Text entry	Pounds		
Payload Capacity	Text	Text entry	Pounds		
Length	Text	Text entry	Inches		
Width	Text	Text entry	Inches		
Propulsion Type	Text	Drop down list	Fuel Electric Hybrid		
Flight Control System (FCS)	Text	Text entry	Custom		

Control Station	Text Image	Text entry Upload	JPG PNG TIFF		will be identified and discussed in Phase 2 of the framework.
Payload	Text Image	Text entry Upload	JPG PNG TIFF		
Automation	Text	Text entry	Custom		
Command and Control (C2) Link	Text	Text entry	Custom		
Frequency	Text	Text entry	Custom		
Power	Text	Text entry	Custom		
FCC Approval	Text PDF	Text entry Upload	Custom		
Data/Telemetry Link	Text	Text entry	Custom		
Frequency	Text	Text entry	Custom		
Power	Text	Text entry	Custom		
FCC Approval	Text PDF	Text entry Upload	Custom		
Flight Termination System	Text	Text entry	Custom		
Flight Recovery System	Text	Text entry	Custom		
AIRCRAFT PROCEDURES					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
Limitations	Text	Text entry	Custom	Carried forward to other phases	The procedures section describes the way the aircraft will be operated and how it will handle off-nominal conditions such as lost link, lost GPS, engine failures, etc. NOTE: Some procedures are likely to be developed during the ORA and subsequent testing phases, thus an initial and final CONOPS are useful to ascertain these changes.
Normal Procedures	Text	Text entry	Custom		
Emergency Procedures	Text	Text entry	Custom		

CREW MEMBERS					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
Minimum Crew	Numerical	Text entry	Custom	Carried forward to other phases	The required crew training, credentials, experience, capabilities, and the maintenance of those elements are critical to the system operation. A system that requires an extremely experienced crew to operate safely may be hazardous to operate with a novice crew. NOTE: Some aspects of crew training are likely to be derived during the ORA and subsequent testing, where it may be determined that specialized training is required. This is another reason to have an initial and final CONOPS to compare across the safety case that is developed.
Crew Credentials	Text	Text entry	Selectable Custom		
Crew Experience	Text	Text entry	Custom		
Crew Responsibilities	Text	Text entry	Custom		
Crew Currency	Text	Text entry	Custom		
Pilot to Aircraft Ratio	Text	Text entry	Custom		

OPERATIONAL SCENARIO DESCRIPTION					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
Mission Description	Text	Text entry	Custom	Carried forward to other phases	The operational scenario description provides an opportunity to summarize how the operation will be conducted and the expansions beyond typical operations that are necessary to authorize the flights.
Type(s) of Operation	Button	Selectable	VLOS Remote VOs Successive VOs BVLOS OOP Night One to Many Other (text)		

OPERATIONAL CONSIDERATIONS - GROUND BASED					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
Geographic Area Description	Text	Text entry	Custom	Carried forward to other phases	The location of where operations will occur and associated ground environment is often a critical aspect of operational flight approvals like Part 107 waivers and 49 USC § 44807 exemptions. Limitations on where a system may be operated can provide an effective tool to reduce exposure risk to persons and property on the ground.
Boundaries	Coordinates	Upload Manual entry	GPS coordinates KML/KMZ Images		
Launch and Recovery Locations	Text	Upload Manual entry	GPS coordinates KML/KMZ Images Custom		
Proximity to Ground Based Non-Participating Persons, Structures, and Vehicles	Text	Text entry	Custom		
Private Property Considerations	Text	Text entry	Custom		
OPERATIONAL CONSIDERATIONS - AIRSPACE					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
Airspace Class	Text	Selectable	A, B, C, D, E, G	Carried forward to other phases	Similar to ground considerations, the exposure for air risk can often be impacted by the airspace environment the system will be operated in. This section also describes technology components, such as UTM and DAA, and coordination efforts with ATC that may become risk mitigations for certain air risk hazards.
Coordination with ATC	Text	Text entry	Custom		
UAS Traffic Management	Text	Text entry	Custom		
Detect and Avoid (DAA)	Text	Text entry	Custom		
Proximity to Non-Participating Aircraft	Text	Text entry	Custom		

METEOROLOGICAL CONDITIONS					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
Flight Rules	Text	Selectable	VFR SFR IFR	Carried forward to other phases	Describe the desired meteorological conditions during which are expected to be encountered during normal operations of the system.
Desired Meteorological Conditions	Text	Selectable	VMC IMC Day/Night Other		
Time of Operations	Text	Selectable	Custom		
Equipage for Non-VMC	Text	Text entry	Custom		
COMMUNICATIONS					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
ATC Communications	Text	Text entry	Custom	Carried forward to other phases	Communications with various groups can provide great strategic risk mitigations. How communication will be established and maintained with appropriate stakeholders should be described in sufficient detail.
General Aviation Comms	Text	Text entry	Custom		
Special Use Airspace/MTR	Text	Text entry	Custom		
Internal Crew Comms	Text	Text entry	Custom		
Community Outreach and Notification	Text	Text entry	Custom		
SECURITY					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**
C2 Link Security	Text	Text entry	Custom	Carried forward to other phases	The security section should describe how integrity of the C2 link will be maintained, if it is required for safe operation, against purposeful interruption. The physical security of the operator and equipment may also be necessary in certain circumstances to ensure safety.
Physical	Text	Text entry	Custom		

3.2 Phase 1b: Operational Risk Assessment

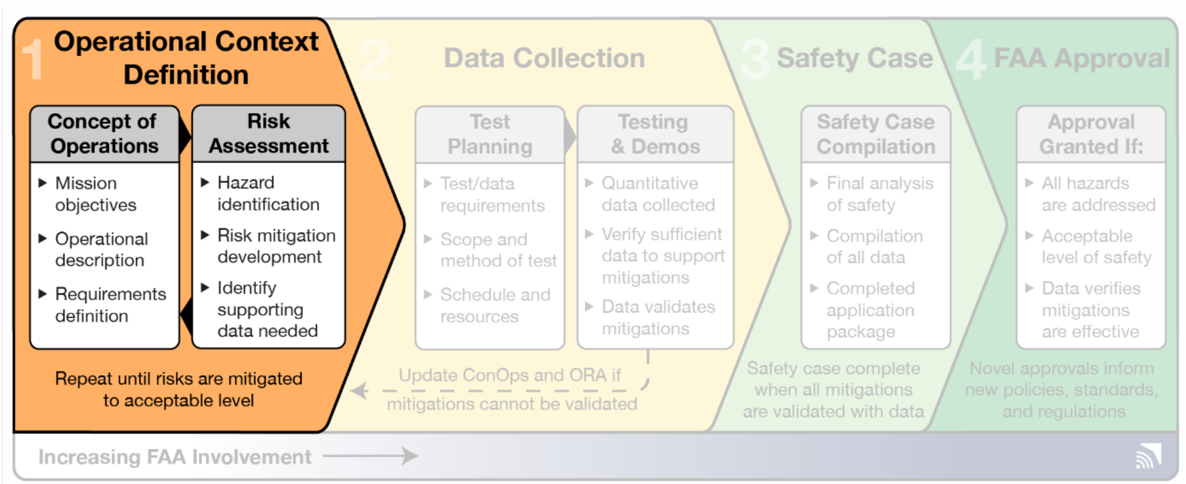
Table 11 provides the data schema for Phase 1b—Operational Risk Assessment. This is divided into the following subsections:

- Metadata
- Air Risk
- Ground Risk

Information provided includes:

- A description of the ORA phase
- Data fields
- Data types
- Suggested input methods
- Input characteristics (e.g., units, data format)
- Relationships to other phases
- Descriptions of subsections, fields, etc.
- Unmitigated Risk Identification category (divided into hazards, pre-mitigation severities, and pre-mitigation likelihoods)
- Mitigated Risk Identification category (divided into mitigation, post-mitigation severities, and post-mitigation likelihoods)
- Prioritization of Risk Mitigations category (divided into criticality, supporting data, and validation required?)
- Data Characteristics category (divided into data type, input methods, and relationships)

Table 11: Data schema for Phase 1b—Operational Risk Assessment.

PHASE OF PROCESS	DESCRIPTION OF DATA SCHEMA
	The ORA lays the foundation for the data collection phase that will come next in the safety-case framework. The linkage of test data to risk mitigations provides the critical context necessary to interpret the data from test reports accurately. The ORA data schema can be standardized in many areas and selectable menus may simplify data entry for many fields. However, there are certain fields that may be more difficult to enter, especially the "supporting data" field that may reference other FAA, industry, or scholarly published documents. The lengthy and repetitive nature of ORAs makes them especially conducive to database systems. Virginia Tech has developed an Access database for this purpose, which was the inspiration for the FAA's prototype database of similar construct.

Virginia Tech
UAS Operational Risk Matrix

Likelihood \ Severity	Minimal	Minor	Major	Hazardous	Catastrophic
Frequent	5n	10a	15a	20a	25n
Probable	4a	8a	12a	16n	20b
Remote	3a	6a	9n	12b	15b
Ext Remote	2a	4b	6b	8b	14 * / 10b
Improbable	1n	2b	3b	4c	8c

High Risk 13.1-25.0
Medium Risk 7.1-13.0
Low Risk 1.0-7.0

*Single Point or Common Cause Failures = Red / 14

METADATA					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description/Notes**
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects, however it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.
Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.
User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.
Keywords	Text	Manual entry Radial buttons	Custom Predefined	Some may be carried from other phases	Keywords may include any number of relevant words. This can be used to identify unique aspects of the ORA. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.

AIR RISK											
Unmitigated Risk Identification			**Mitigated Risk Identification**			**Prioritization of Risk Mitigations**			**Data Characteristics**		
Hazard	**Pre-Mitigation Severity**	**Pre-Mitigation Likelihood**	**Mitigation**	**Post-Mitigation Severity**	**Post-Mitigation Likelihood**	**Criticality**	**Supporting Data**	**Validation Required?**	**Data Type**	**Input Method**	**Relationships**
Air Risk Hazard A NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase
	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase
Air Risk Hazard *n+1* NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase
	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase

GROUND RISK											
Unmitigated Risk Identification			**Mitigated Risk Identification**			**Prioritization of Risk Mitigations**			**Data Characteristics**		
Hazard	**Pre-Mitigation Severity**	**Pre-Mitigation Likelihood**	**Mitigation**	**Post-Mitigation Severity**	**Post-Mitigation Likelihood**	**Criticality**	**Supporting Data**	**Validation Required?**	**Data Type**	**Input Method**	**Relationships**
Ground Risk Hazard A NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase
	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase
Ground Risk Hazard *n+1* NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase
	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase

3.3 Phase 2a: Test Planning

Table 12 provides the data schema for Phase 2a—Test Planning. This is divided into the following subsections:

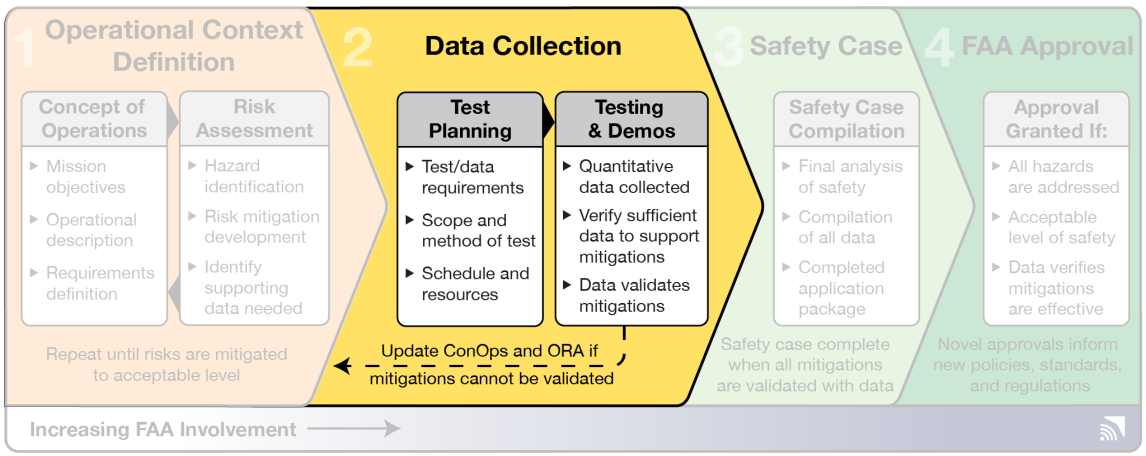
- Metadata
- Narrative Format

Information provided includes:

- A description of the Test Planning phase
- Data fields
- Data types
- Suggested input methods
- Input characteristics (e.g., units, data format)
- Relationships to other phases
- Descriptions of subsections, fields, etc.
- Test Requirements category
- Data Requirements category
- Required Resources category
- Test Execution category
- Deliverables category

Table 12: Data schema for Phase 2a—Test Planning.

PHASE OF PROCESS



DESCRIPTION OF DATA SCHEMA

All data provided in the CONOPS and ORA are carried over to the test-planning section. This includes the configuration of the system, crew qualifications, and more. The ORA provides the context of the risk mitigations that will be tested.

Differences from the CONOPS must be noted in the test plans and explained. There may be reasonable justifications for differences from the CONOPS, such as the addition of test equipment onto the aircraft, truth data sources, etc.

DATA TYPE EXPECTED:
Narrative-format test plans that contain the information following the metadata section. The narrative-format allows for flexibility in the method used to capture and report data, but also becomes challenging to query and search. To address this, a strong emphasis is placed on providing keywords in the metadata about the testing. Any query made by a user of the system should return the test report along with the full safety case file so that all contextual information is also provided with the test report.

METADATA					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description/Notes**
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects, however it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.

Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.
User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.
Test Name	Text	Manual entry	Custom	Carried forward to test reports	Allow for custom naming of tests. However, it may be possible to create a standardized test name structure that helps identify tests that may be similar in nature across various users.
Test Number	Text	Manual entry	Custom	Carried forward to test reports	Allow for custom numbering of tests.
Test Objective	Text	Manual entry	Custom	Carried forward to test reports	Custom input is important because test objectives may vary widely and, therefore, result in a list too long to possibly predefine.
Hazard Category	Text	Drop down list	Mid-Air Collision Ground Collision – Persons Ground Collision – Property	Carried from ORA Carried forward to test reports	The input options listed here come from the UASTS OTA (Unmanned Aircraft System Test Site Other Transaction Agreement). An alternative would be to use just simply “Air Risk” and “Ground Risk”.
Specific Hazard	Text	Manual entry	Custom	Carried from ORA Carried forward to test reports	This is the specific hazard that could be realized and therefore must be mitigated against.

Risk Mitigation	Text	Manual entry	Custom	Carried from ORA Carried forward to test reports	This is the specific mitigation that has been put in place to prevent the hazard above from being realized.
Validation Method	Text	Drop down list or Radial buttons	Ground Test Flight Test Simulation Functional Demo Analysis	Carried forward to test reports	The basic method of validation is identified here. Demonstrations are distinguished from tests because they are designed to showcase a certain functionality, but perhaps without testing some statistically significant number of samples.
Keywords	Text	Manual entry Radial buttons	Custom Predefined	Carried forward to test reports	Keywords may include any number of relevant words. This can be used to identify unique types of test methods, test articles, weather conditions, etc. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.

<table>
<tr><th colspan="2">NARRATIVE FORMAT (Example Contents)</th><th>DISCUSSION</th></tr>
<tr><td>Test Requirements</td><td>Description</td><td rowspan="3">The Safety-Case Framework outlined in Task 1 of this project includes the following assessment: “A near-infinite number of possible data components could be listed, depending upon the question under investigation. Therefore, it is proposed that no complete list of data components can be defined, but instead the process should be utilized to identify, define, and collect the proper data for the question at hand.”

To this end, the team proposes that the exact format and contents of these narrative elements cannot be predefined,</td></tr>
<tr><td>Location
Environmental Conditions
Required Crewmember Qualifications
Test Article Configuration
Differences from CONOPS</td><td>The test requirements should fully explain the requirements that must be met in order to conduct the test. Specific attention should be paid to utilizing the properly configured test article operated by the appropriate crew in the necessary weather conditions.</td></tr>
<tr><td>Data Requirements</td><td>Description</td></tr>
</table>

Position of RPIC Ownship position truth data Intruder position truth data Distance between ownship and intruder Closest point of approach	The data requirements section defines what data must be collected and how they will be collected. This is critical to ensuring that all necessary variables are collected and with sufficient accuracy. This list could be infinitely long, but might be standardized for certain tests.	especially to maintain scalability of this process for things beyond just Part 107 waivers. However, it may be possible standardize the major components for specific scenarios (e.g. Part 107 waiverable provisions) to at least identify the topics that must be addressed and desired formats of the data contained therein. Additionally, industry consensus standards could be utilized to normalize the structure and organization of narrative documents.
Required Resources	**Description**	
Test article components Test equipment Software Data acquisition devices	Identifies any specific hardware, software, and other resources that are needed to execute the tests. Specific configurations of each resource should be specified.	
Test Execution	**Description**	
Test safety considerations Test dependencies Step-by-step instructions to complete test	Describes test-specific safety considerations and dependencies that must be met in order to continue testing. Instructions for completing the test should be sufficient to enable others to repeat the test accurately.	
Deliverables	**Description**	
Expected outputs of test Success criteria	Provides a preview of what the results of the test should look like so that real-time assessment of test validity and occur during test execution. Also predefines success criteria so that a satisfactory test can be determined quickly.	

3.4 Phase 2b: Test Data/Reports

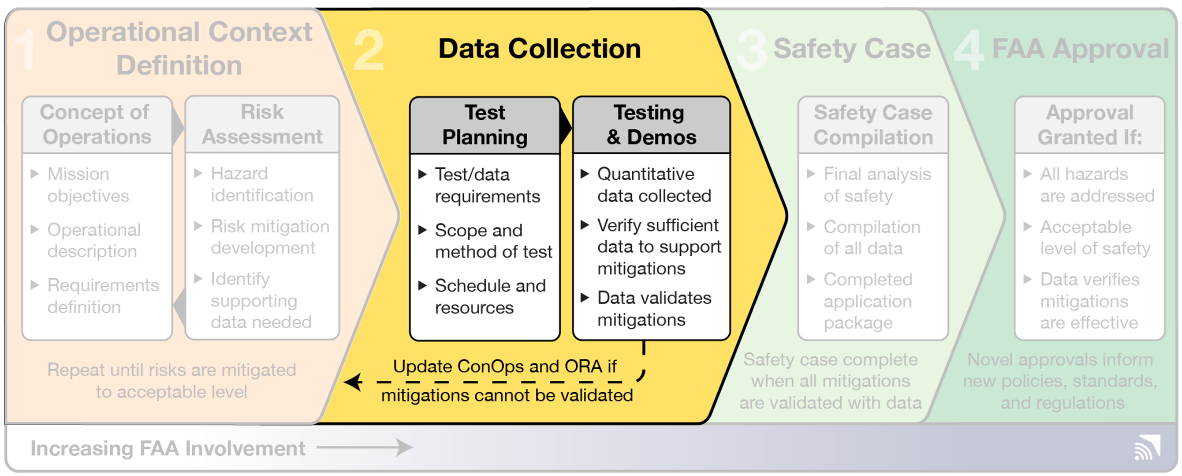
Table 13 provides the data schema for Phase 2b—Test Data/Reports. This is divided into the following subsections:

- Metadata
- Narrative Format

Information provided includes:

- A description of the Test Data/Reports phase
- Data fields
- Data types
- Suggested input methods
- Input characteristics (e.g., units, data format)
- Relationships to other phases
- Descriptions of subsections, fields, etc.
- Test Execution category
- Test Data category
- Test Article category
- Results category

Table 13: Data schema for Phase 2b—Test Data/Reports.

<table>
<tr><th>PHASE OF PROCESS</th><th>DESCRIPTION OF DATA SCHEMA</th></tr>
<tr><td>


</td><td>
All data provided in the CONOPS and ORA are carried over to the test data section. This includes the configuration of the system, crew qualifications, and more. The ORA provides the context of the risk mitigations that will be tested.

Differences from the CONOPS must be noted in the test plans and explained. There may be reasonable justifications for differences from the CONOPS, such as the addition of test equipment onto the aircraft, truth data sources, etc.

DATA TYPE EXPECTED:
Narrative-format test plans that contain the information following the metadata section. The narrative-format allows for flexibility in the method used by to capture and report data, but also becomes challenging to query and search. To address this, the strong emphasis is made on providing keywords in the metadata about the testing. Any query made by a user of the system should return the test report along with the full safety case file so that all contextual information is also provided with the test report.
</td></tr>
</table>

METADATA

Field	Data Type	Input Method	Input Options	Relationships	Description/Notes
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects. However, it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.

Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.
User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.
Test Name	Text	Manual entry	Custom	Carried from test plan	Allow for custom naming of tests, however, it may be possible to create a standardized test name structure that helps identify tests that may be similar in nature across various users.
Test Number	Text	Manual entry	Custom	Carried from test plan	Allow for custom numbering of tests.
Test Objective	Text	Manual entry	Custom	Carried from test plan	Custom input is important because test objectives may vary widely and therefore result in a list too long to possibly predefine.
Hazard Category	Text	Drop down list	Mid-Air Collision Ground Collision – Persons Ground Collision – Property	Carried from test plan	The input options listed here come from the UASTS OTA. An alternative would be to use just simply “Air Risk” and “Ground Risk”.
Specific Hazard	Text	Manual entry	Custom	Carried from test plan	This is the specific hazard that could be realized and therefore must be mitigated against.
Risk Mitigation	Text	Manual entry	Custom	Carried from test plan	This is the specific mitigation that has been put in place to prevent the hazard above from being realized.

Validation Method	Text	Drop down list or Radial buttons	Ground Test Flight Test Simulation Functional Demo Analysis	Carried from test plan	The basic method of validation is identified here. Demonstrations are distinguished from tests because they are designed to showcase a certain functionality, but perhaps without testing some statistically significant number of samples.
Keywords	Text	Manual entry Radial buttons	Custom Predefined	Carried from test plan	Keywords may include any number of relevant words. This can be used to identify unique types of test methods, test articles, weather conditions, etc. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.

NARRATIVE FORMAT (Example Contents)		**DISCUSSION**
Test Execution ("as tested")	**Description**	The test results should be simple evaluations of the test plans. Detailed test planning ensures that the method of the test closely aligns with the test plan and that the test results meet expectations of the test. Careful consideration must be given when there are differences in how the test was actually conducted, versus how it was planned. This is a common occurrence and may have negligible to significant impact on the results. Thus, differences must be tracked and explained in the final test report. The test reports identify whether the objectives were met at the end of the testing. The success criteria should have been established during the planning phase and therefore it is straightforward to determine if the risk mitigations proposed in the CONOPS/ORA were successful. If they were not successfully validated, then the framework requires that the CONOPS and ORA
Location Environmental Conditions Crewmember Qualifications Test Article Configuration Differences from Test Plan	Describes how the test was actually conducted. Differences or exceptions from the test plan must be clearly identified and explained. The effect of differences must be evaluated to ascertain if the test was executed in a manner that met the original objectives.	
Test Data	**Description**	
Position of RPIC Ownship position truth data Intruder position truth data Distance between ownship and intruder	Provide the actual test data from the testing, often data that has been analyzed will be primarily presented, but raw data may be included as supplementary data or as an appendix. Fields shown here are	

Closest point of approach	representative carry overs from the test plan.	must be revisited to determine if there is a need to alter the operation or consider additional risk mitigations.
Test Article ("as tested")	**Description**	
Test article components Test equipment Software Data acquisition devices	Identifies the test articles and their configuration in how they were actually tested. Differences from the test plan must be explained and justified.	
Results	**Description**	
Analysis of test data Discussion of analysis Conclusion from test results	Discusses how the data collected during the test meets, or does not meet, the objective of the test. Identifies if the test was conducted in an acceptable manner. Determines if the desired results were achieved and if the risk mitigation was validated.	

3.5 Phase 3: Safety Case

Table 14 provides the data schema for Phase 3—Safety Case. This is divided into the following subsections:

- Metadata
- Narrative Format

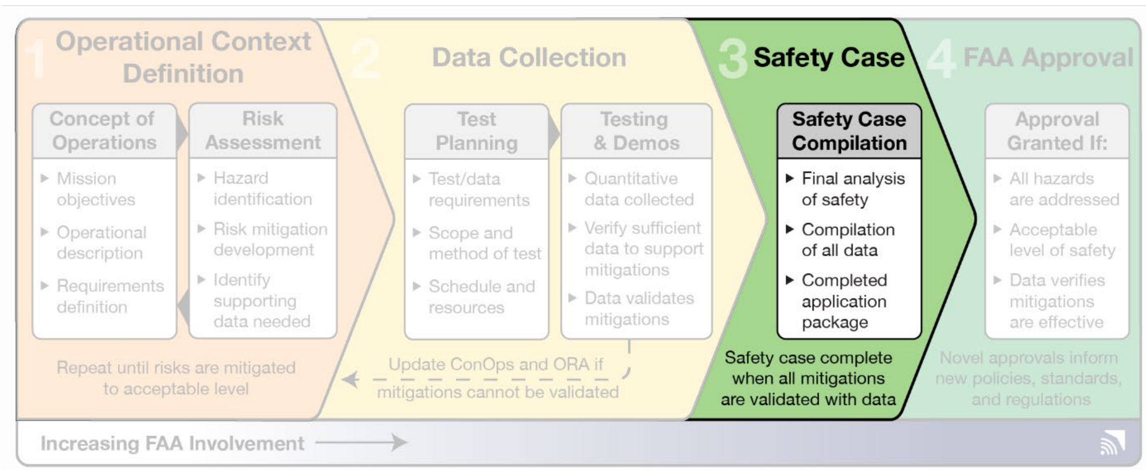
Information provided includes:

- A description of the Test Data/Reports phase
- Data fields
- Data types
- Suggested input methods
- Input characteristics (e.g., units, data format)
- Relationships to other phases
- Descriptions of subsections, fields, etc.
- Safety Case Elements category

3.6 Phase 4: FAA Approval

Since this phase involves submission of a safety case to the FAA for review, it does not have an associated data schema.

Table 14: Data schema for Phase 3—Safety Case.

<table>
<tr><th>PHASE OF PROCESS</th><th>DESCRIPTION OF DATA SCHEMA</th></tr>
<tr><td>


</td><td>The safety case is a compilation of all the previous phases that is summarized to explain the overall safety of the operation. Therefore, this is typically a narrative document that references the previous phases in the safety case development process. A narrative document would be uploaded to the database with associated metadata that captures the context from previous phases.

Like the other phases that contain that narrative documents (2a and 2b), there is a strong emphasis on keywords to aid querying of the documents. The metadata associated with all of the phases ensures that a query that returns a result from any single phase will also include the entirety of the safety case from initial CONOPS to final safety case.</td></tr>
</table>

METADATA

Field	Data Type	Input Method	Input Options	Relationships	Description/Notes
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects. However, it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.
Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.
User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.

Keywords	Text	Manual entry Radial buttons	Custom Predefined	Some may be carried from other phases	Keywords may include any number of relevant words. This can be used to identify unique types of test methods, test articles, weather conditions, etc. The keywords input is critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.

NARRATIVE FORMAT (Example Contents)		**DISCUSSION**
Safety Case Elements	**Description**	As mentioned in the description of data schema above, the safety case is compilation of all of the previous phases of the safety-case framework. As such, much of the document will summarize previous documents and provide references regarding where to find information in the supporting documents. The actual safety case document is normally tremendously lengthy, as details are provided in the often-lengthy reference documents. Instead, it should succinctly identify the approach taken to ensuring safety, explain the CONOPS, identify major hazards and risk mitigations, and then provide an assessment of the level of safety.
Purpose	Describes why the safety case was sought, including how the expanded operation will benefit the organization, customers, and society.	
Regulatory Authority	Identifies what regulatory authority the safety case is seeking to use for expanded operations (e.g., specific Part 107 waiverable provisions, 44807 exemptions, TC, etc.).	
Safety Case Method/Process	Explains the methodology employed during the development of the safety case.	
CONOPS Summary	Summarizes the major components of the concept of operations, including the type of UAS and how it is operated and maintained.	
ORA Summary	Summarizes the ORA process and expected final level of safety for the operation.	
Primary Hazards	Describes the primary hazards identified for the operation and any unique features of those hazards.	

Mitigation Strategies	Provides a high-level overview of the mitigation strategies for the identified hazards. References the detailed ORA for the specifics of the risk mitigations.
Guiding Questions and Answers	Optional section that provides detailed answers to the FAA's Part 107 waiver guidance questions and where detailed information may be found in the supporting documents.
Level of Safety Finding	Combines all the above information and the results from all testing to determine the ultimate level of safety established by the safety case.
Appendices	CONOPS, ORA, Test Plans, and Test Report are often provided as appendices. Other supporting documents might include industry standards, technical papers from third parties, and other previous test results.

4 Review Process

4.1 Review of Existing Approaches

Over the course of this effort, the ASSURE team conducted a systemic review of current processes, methods and "best practices" for UAS safety data collection from major stakeholders. While the focus was on more mature organizations (e.g., UAS Test sites, public agencies with frequent UAS use, and industry with substantial current or planned UAS operations), other viable data sources were considered as well. Engaging those organizations with high process maturity allowed the researchers more insight into the reasons why certain data are selected, captured and stored, the initial utility of that data to both the organization (and to agencies they report to such as the FAA), and any key decisions made to select new or deselect previous data items based upon ultimate utility.

In addition, the more established and formalized processes used to collect safety data for manned aircraft operations were examined. The focus was on identifying the key steps in the collection process, reviewing the scope and types of data elements, and determining which of those elements were deemed most useful/most frequently cited/accessed by end users for safety-related purposes.

4.2 FAA Reviews

Throughout the process of safety-data schema research and development, the FAA project sponsors were informed of progress through monthly Technology Interchange Meetings (TIMs). These allowed input to and feedback from the researchers on the key observations, assumptions, and decisions that affected the development of the proposed schema.

This project was designed with two formal FAA reviews of the proposed data schema. Thus, Tasks 3 and 5 were formal reviews, and corresponding Tasks 4 and 6 were revisions based upon FAA feedback. To meet this project's Task 3 deliverable for an FAA review of the proposed system, the research team met with the FAA on 26 June 2019 to:

a) Brief the FAA on the approach, methodology and processes used to identify, select, validate and format the UAS safety-data elements;
b) Present the proposed data elements in a defined form (schema);
c) Note comments, observations, questions and other feedback from the FAA sponsors and identified stakeholders;
d) Compile the results of the review into a set of action items to serve as a baseline for needed revisions to the schema.

Following the successful FAA Task 3 review, the researchers used the feedback to modify the schema to support the needs identified by the FAA sponsors. To ensure consistency of structure and use, schema modifications were subjected to the same process rigor of identification, validation, and data standardization that was applied to the initial efforts. Results were socialized extensively throughout the research team, and summary updates were again provided through FAA TIMs as well as to other ASSURE members through monthly telecons.

Once the schema modifications and internal review were complete and all comments/concerns were adjudicated, the research team conducted the second (Task 5 review) with the FAA on 23 October 2019. In this review, the FAA provided feedback that made it apparent that the data schema focus was, at that time, too narrow, with emphasis on test data and not enough material regarding the other phases of the safety-case framework. Based upon that feedback, the second revision of the data schema, which was presented to the FAA on 18 March 2020, was determined to provide better alignment with FAA needs. The conclusion of the review process finalized the baseline schema for the proposed system.

It is noted that while inclusion of FAA sponsor reviews was critical to the development of the proposed safety case framework and data schema, these reviews do not constitute an endorsement by the FAA. Success from that standpoint will be apparent if the test data collection and analysis system being developed in this research arc is adapted and utilized (and if the questions that define the scope of this research arc are satisfactorily answered).

4.3 Final Research Team Review

4.3.1 Process

As one final review, operations personnel from three FAA UAS Test Sites, the NMSU Unmanned Aircraft Flight Test Site, the Northern Plains UAS Test Site (NPUASTS), and the UAF UAS Test Site, evaluated the data Schema for the completeness of the schema and the value of the elements in the schema in a two-step process. The first step involved asking the teams to independently review each of the five worksheets (CONOPS, ORA, Test Plans, Test Data, and Safety Case) that cover the four phases of the safety case development (Operation Context Definition, Data Collection, Safety Case, and FAA Approval) and determine:

- What information is missing for each area?
- What information is not clear?
- What information is unnecessary?
- Are the units correct?
- Any other comments?

After the teams spent time getting familiar with the contents of the worksheets and provided their comments, they were asked to go back to the worksheets and assign an 'Assessment Weighting' factor to each element of the schema. The weighting factor provided the teams with a way to identify what items they felt were the most important to collect and identify any pieces of information that were deemed to be unnecessary. The 'Assessment Weighting' factors were quantified as:

1. Core value data/parameter
2. Valuable data/parameter
3. Additional (potentially helpful) data/parameter
4. Minimal value data/parameter
5. Remove

Five members of the NMSU team, four members of the NPUASTS team, and six members of the UAF team completed the review. The results of the two phases of the review are included in the Data Schema workbook titled, "A19 Data Schema – DRAFT (Combined UAF NMSU UND) Final Form" (provided separately as a project document). For clarity and brevity, the individuals' comments and assessment weighting factors were collapsed into a single column of comments and an average of assessment weighting factors for each team and are not presented as individual results in the workbook. The averages of the individual teams' weighting and the three-team average are provided to show the similarity and differences between the teams' opinions.

The average assessment weighting factors are color coded for easy identification of the value of the element as assessed by the team. The scoring system shown above was used to assess the average element score across the scoring spectrum. This weighting scale derived from above using the averaged values resulted in the following assessment ranges:

Score between 1.0 and 1.5 (Core value data/parameter).
Score between 1.6 and 2.5 (Valuable data/parameter).
Score of 2.6 and above (Additional [potentially helpful] data/parameter).

Elements in the workbook with no background color have weighting factors between 1.0 and 1.5 (Core value data/parameter). Elements with yellow background color have weighting factors between 1.6 and 2.5 (Valuable data/parameter). Elements with red background color have weighting factors of 2.6 and above (Additional [potentially helpful] data/parameter). None of the average assessment weighting factors for the elements in the data schema received a value above 3.0.

4.3.2 Results

The results of the first step (comments) review showed that the teams are content with the content included in the ORA (no comments received), Test Plans (minor comments received), Test Data (minor comments received), and Safety Case (no comments received) worksheets. The CONOPS worksheet received a significant number of comments that were mostly related to format (e.g., adding drop-down lists), clarification of terms (e.g., definitions, units, explanations), and potential additions (e.g., N/A options, more lines for different frequency links, security badging information). The NMSU team raised a good point that the schema is concentrating on the sUAS aspect of flight operations and possibly not the larger UAS flight operations. It would be beneficial to ensure that this data schema is adaptable to larger UAS operations. The NMSU team also requested that the workbook be modified, by worksheet or sub-topic area, to allow the input of any additional information that had not been captured or noted in the categories currently listed in the worksheets. The NMSU team identified that a "catch all" category should be added somewhere for new, evolving, or different items.

The results of the assessment weighting exercise show that the teams' average assessment weightings are consistent; for example, items rated 'valuable' by one team are usually rated 'valuable' by all the teams. One of the key findings in this assessment is that, with very few exceptions, all of the elements in the data schema were given a rating of 2.5 or better, corresponding to a classification of 'core value' or 'valuable' data/parameter by all of the teams. This shows that the data schema has been successfully optimized to collect data elements that the teams agree are important for documenting the four phases of safety case development. Although there are a few team average values below 2.5, the only item below 2.5 in the 'All' sites average assessment weighting is: 'Aircraft picture' on the CONOPS spreadsheet. Table 15 shows the items rated by 'All' on the low side of 'valuable' (2.0-2.5).

Table 15: Data elements rated between 2.0 and 2.5 (low side of 'valuable') by phase.

CONOPS (1a)	ORA (1b)	Test Plans (2a)	Test Data (2b)	Safety Case (3)
Keywords	User	User	Keywords	Title
Payload Capacity		Keywords	Crewmember Qualifications	User
Width				Keywords
Payload				
Crew Experience				
Crew Currency				
Private Property Considerations				
Community Outreach and Notification				

The lower-valued items in Table 15 can be grouped into several classes. ‘User’ and ‘Keywords’ are consistently valued lower than 2.0 and, where these items are not listed in the table, they rated more important and have a value of 1.8 or 1.9. The overall rating of 'Keywords' is in contrast to a comment that 'Keywords' is an important factor to include in each of the sections of the data schema. All the items related to the crew were also rated lower than other items; if a specific item did not make the table, that item’s rating was usually close to 2.0. The aircraft’s payload and physical parameters, other than weight, were rated on average around ‘valuable’ (1.8-2.3). ‘Private Property Considerations’ and ‘Community Outreach and Notification’ were the last two items the teams felt, on average, were not as essential to the operations.

The overall review process has confirmed that following the data schema will collect information the Test Site operational teams have determined to be of value to conducting the four phases of a safety case development. The review did identify several additional parameters or elements that could be included (e.g., inclusion of restricted flight areas). The teams did not identify any extraneous information (‘Minimal value data/parameter’ or ‘Remove’) in the data schema.

5 Software and Hardware Requirements

One of the project tasks is evaluation of software and hardware requirements for the data collection system. These were evaluated for support of this and future research projects. Requirements for operational use (especially hardware requirements), are likely to be more significant.

Software requirements for such a system are fairly straightforward. From a functionality standpoint, software is needed to collect information from the user. This software must be able to ‘handle’ multiple types of data (numerical, text, images, documents)—depending upon the data element being provided. Additional software must store the information. This can be accomplished in a variety of ways. However, use of a database is likely preferred, as such a system enables subsequent analyses.

Since the data schema developed herein differs significantly from those used elsewhere [e.g., the COA online system (FAA 2020)], it was determined that a new system would be needed. To provide flexibility, it is recommended that this system employ a web-based interface. Such an interface is utilized, for instance, with the COA online system, the Mission Logging System (MLS) utilized by the FAA Test Sites, and the data collection system used in the UAS IPP. Furthermore, it is expected that data will be stored in a database to enable subsequent use of data in analyses.

Because these data are associated with a safety case and are not operational data, the volume of data that must be stored for any specific safety case is modest. Given this and the other research-related requirements, a modest desktop system was acquired for testing and prototype system development. This system has the following characteristics:

Operating System: Windows Server 2016 Standard
Processor: Intel core I5
Storage: 500 GB drive

It is noted that for an operational system, the number of concurrent users, number of safety cases (disk-space requirements), software to be used for data analysis, system maintenance and down time, etc., should be considered.

6 Demonstration

A demonstration system was developed to solicit input from potential users (test site members that were a part of this research project) regarding input methods and design. This demonstration system was first used during Fall 2019 to solicit input from the NPUASTS. In Spring 2020, this system was modified based upon the final data schema revision and used to solicit input from the rest of the test site members. This demonstration system did not encompass all data elements and did not communicate with a data storage system. It did, however, include a variety of data types (text, drop-down selection, file upload, etc.). A sample image of the demonstration system is provided in Figure 6.

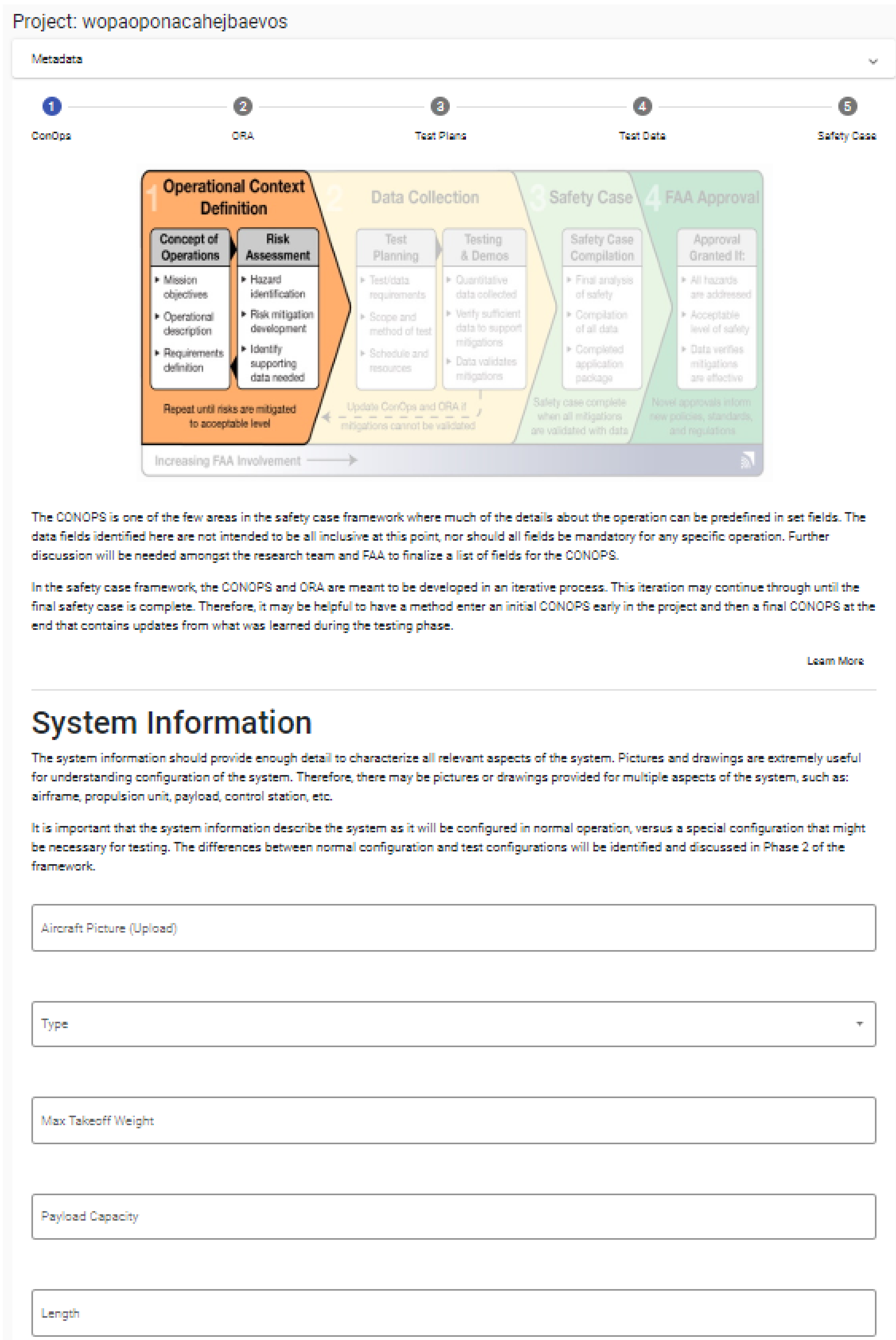


Figure 6: Illustration of the demonstration data collection system.

This system provides a base-line build for the prototype system that is being built in Phase II of this project. Recent feedback garnered using this system focuses on ease of use issues such as ensuring that the Metadata section is not missed by the user, enabling resizing of text boxes to make management of long entries easier, possible use of rich text, enabling the user to collapse/expand certain sections, and enabling users to save as they go (e.g., by section).

7 Training Materials

Material that explains the philosophy and organization of the safety-case framework and provides information regarding data elements will enable system utilization. To that end, the following material has been developed.

7.1 Safety-Case Collection System Description

Thank you for participating in the efforts to collect data in a uniform manner to assist the FAA and other regulatory bodies to continue to verify and validate existing risk mitigation strategies. The data collected provides a logical flow from an industry driver (i.e., business case) through a process that encourages traceability of data, and the associated context of those data, to a completed safety case that can inform FAA decision making on numerous fronts. It should be noted the this system does not attempt to define all possible data elements that might be collected in a test program, but instead focuses on establishing a repeatable framework to collect data as well as on refining the appropriate data that should be collected from relevant test programs.

As you complete each section/module, the data fields will have a ?. This icon will provide additional information to assist the user in providing data in a standardized format. It is critical that data provision be standardized as to enable processing and analysis of the collected data.

The data collection framework is comprised of the following five sections/modules:

1) **CONOPS** - The CONOPS is one area in the safety-case framework where much of the details about the operation can be predefined in set fields. The defined set of data fields is expected to evolve, with those incorporated now comprising a core set. It is noted that it is not expected that every identified data element be provided by the user.
2) **ORA** - The Operational Risk Assessment (ORA) lays the foundation for the data collection. The linkage of test data to risk mitigations provides the critical context necessary to interpret the data from test reports accurately. The ORA data schema is standardized with selectable menus to simplify data entry for many fields. However, certain fields, especially the "supporting data" field that may reference other FAA, industry, or scholarly published documents, may require typing or attaching files.
3) **Test Plans** - Test plans establish the who, what, why, when, where, and how the system will be tested. Each of these items is a relevant data source to the overall safety case. This includes the configuration of the system, crew qualifications, and more. The ORA provides the context of the risk mitigations that will be tested. Differences from the CONOPS must be noted in the test plans and explained. There may be reasonable justifications for differences from the CONOPS, such as the addition of test equipment onto the aircraft, truth data sources, etc.
4) **Test Data** - Raw test data can take innumerable forms, but this is the source of data that lays the building blocks for the successful validation of risk mitigations. Use of keywords has been provided to assist in uniformly capturing and querying the data.
5) **Safety Case** - The safety case should succinctly identify the approach taken to ensure safety and provide an assessment of the level of safety that will be accepted.

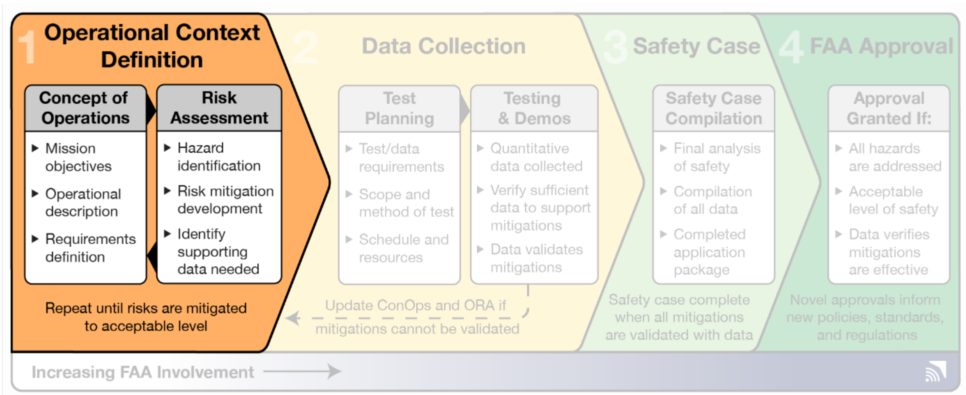
Data collection presented here has numerous potential environmental outcomes that further the UAS industry and integration of UAS into the NAS. Specifically, the direct outcomes from a successful safety case include new approvals, which may contain proprietary data, in the form of waivers, exemptions, aircraft certifications, etc. Indirect outcomes provided by your efforts include the collection of new data to support regulations, policies, guidance, standards, and best practices for UAS, the enabling of new markets (e.g. Urban Air Mobility), and an overall reduction in risk that may be achieved by performing some missions with UAS technology.

Thank you for your participation

7.2 Help Information for Data Elements

Suggested help information is provided in Tables 16-20. In addition to providing context to the user, this help information is intended to ensure consistency in data entry (e.g., usage of the same units for data elements). As the system evolves, this help information is expected to evolve as well.

Table 16: Help information for Phase 1a—Concept of Operations. Help information is provided in the right-most column. Some text is diminished in size for space considerations.

PHASE OF PROCESS	DESCRIPTION OF DATA SCHEMA	? HELP
	The CONOPS is one of the few areas in the safety-case framework where much of the details about the operation can be predefined in set fields. The data fields identified here are not intended to be all inclusive at this point, nor should all fields be mandatory for any specific operation. In the safety-case framework, the CONOPS and ORA are meant to be developed in an iterative process. This iteration may continue through until the final safety case is complete. Therefore, it may be helpful to have a method enter an initial CONOPS early in the project and then a final CONOPS at the end that contains updates from what was learned during the testing phase.	

METADATA						? Help
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description/Notes**	
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects. However, it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.	Enter project identifier (used to track projects). Project identifiers must be unique to each project.
Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.	Enter title of project used to describe this project.

User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.	Enter user information, which generally is the name of the person leading entry of information and the organization/program.
Keywords	Text	Manual entryRadial buttons	CustomPredefined	Some may be carried from other phases	Keywords may include any number of relevant words. This can be used to identify unique aspects of the CONOPS. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.	Keywords may include any number of relevant words. These can be used to identify unique types of test methods, test articles, weather conditions, etc.
SYSTEM INFORMATION						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
Aircraft Picture	Image	Upload	JPG PNG TIFF	Carried forward to other phases to inform standard system configuration.	The system information should provide enough detail to characterize all relevant aspects of the system. Pictures and drawings are extremely useful for understanding configuration of the system. Therefore, there may be pictures or drawings provided for multiple aspects of the system, such as: airframe, propulsion unit, payload, control station, etc. It is important that the system information describe the system as it will be configured in normal operation, versus a special configuration that might be	The picture should reflect the most likely configuration in which the UAS operations will occur. For example, if DAA equipment is installed on the aircraft, the picture should include the DAA equipment attached to the UAS, in the picture. In addition, a schematic of how supporting systems (e.g., DAA) interfaces with aircraft systems would be helpful. A 3-view drawing of the aircraft should be provided if available.

Type	Text	Drop down list	Fixed wing Helicopter Multirotor Hybrid	necessary for testing. The differences between normal configuration and test configurations will be identified and discussed in Phase 2 of the framework.	Hybrid - Type - consists of an aircraft that has the ability to fly as an aircraft with the wings fixed in one location and being able to be reconfigured to fly as a multirotor or helicopter.
Max Takeoff Weight	Text	Text entry	Pounds		The maximum allowable weight for takeoff specified by the Original Equipment Manufacturer.
Payload Capacity	Text	Text entry	Pounds		This is the maximum weight the UAS is carry. This includes such things as sensors or packages.
Length	Text	Text entry	Inches		The length should be in ft/in or meters.
Width	Text	Text entry	Inches		The width should be in ft/in or meters.
Propulsion Type	Text	Drop down list	Fuel Electric Hybrid		Hybrid - Type - consists of an aircraft that has the ability to use Fuel and Electric as a propulsion type.
Flight Control System (FCS)	Text	Text entry	Custom		UA's system that allows the aircraft to be controlled remotely either directly by a pilot or autonomously by an onboard computer. The primary hardware component of the FCS is the autopilot and related software. FCS can also include GCS (Ground Control System) and other hardware/software onboard the aircraft.
Control Station	Text Image	Text entry Upload	JPG PNG TIFF		Control station means an interface used by the remote

					pilot to control the flight path of the small unmanned aircraft.
Payload	Text Image	Text entry Upload	JPG PNG TIFF		This is the weight the UAS can carry above its empty weight. This includes such things as sensors, fuel, and packages.
Automation	Text	Text entry	Custom		What type of autopilot is used to control the aircraft.
Command and Control (C2) Link	Text	Text entry	Custom		The data link between the remotely-piloted aircraft and the remote-pilot station for the purposes of managing the flight.
Frequency	Text	Text entry	Custom		Frequency or frequencies used for C2.
Power	Text	Text entry	Custom		Transmission power in watts and Decibel-milliwatts (dBm)
FCC Approval	Text PDF	Text entry Upload	Custom		Include the Federal Communications Commission (FCC) grant of equipment authorization and FCC ID number for each emitter on the sUA (small Unmanned Aircraft) or drone or at the pilot station.
Data/Telemetry Link	Text	Text entry	Custom		The link between the remotely-piloted aircraft and the remote pilot station for the purposes obtaining data or telemetry such as a video feed.
Frequency	Text	Text entry	Custom		Frequency or frequencies Data/Telemetry Link.
Power	Text	Text entry	Custom		Transmission power in watts and Decibel-milliwatts (dBm).
FCC Approval	Text PDF	Text entry Upload	Custom		Include the FCC grant of equipment authorization and

Field	Data Type	Input Method	Input Options	Relationships	Description	? Help
						FCC ID number for each emitter on the sUA or drone or at the pilot station.
Flight Termination System	Text	Text entry	Custom			Description of the flight termination system provided by the OEM (Original Equipment Manufacturer)
Flight Recovery System	Text	Text entry	Custom			Description of the flight recovery system provided by the OEM.
AIRCRAFT PROCEDURES						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
Limitations	Text	Text entry	Custom	Carried forward to other phases	The procedures section describes the way the aircraft will be operated and how it will handle off-nominal conditions such as lost link, lost GPS, engine failures, etc. NOTE: Some procedures are likely to be developed during the ORA and subsequent testing phases, thus an initial and final CONOPS are useful to ascertain these changes.	Describe limitations associated with the aircraft.
Normal Procedures	Text	Text entry	Custom			Describe how the aircraft is operated.
Emergency Procedures	Text	Text entry	Custom			Describe how off-nominal conditions (e.g., lost-link, engine failure, etc.) are handled.
CREW MEMBERS						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
Minimum Crew	Numerical	Text entry	Custom	Carried forward to other phases	The required crew training, credentials, experience, capabilities, and the maintenance of those elements are critical to the system operation. A system that requires an extremely experienced crew to operate safely may be hazardous to operate with a novice crew. NOTE: Some aspects of crew training are likely to be derived during the ORA and subsequent testing, where it may be	Minimum crew required to meet Safety Case Guidelines.
Crew Credentials	Text	Text entry	Selectable Custom			Multiple fields can be selected - UAS Part 107 Certification, Private Pilot, Commercial Pilot, Instrument rating, Multiengine rating, Certified flight instructor.
Crew Experience	Text	Text entry	Custom			Includes logged flight hours in a registered sUAS (small Unmanned Aircraft System). Hours recorded during manned

					determined that specialized training is required. This is another reason to have an initial and final CONOPS to compare across the safety case that is developed.	flight can also be included to reflect crews overall ADM (Aeronautical Decision Making) experience related to flight operations.
Crew Responsibilities	Text	Text entry	Custom			Multiple fields - Pilot Operator, Sensor Operator, Visual Observer, Mission Commander, Other - List
Crew Currency	Text	Text entry	Custom			UAS flight hours logged in last 90 days.
Pilot to Aircraft Ratio	Text	Text entry	Custom			If One-to-Many approval has been obtained, how many UAS is the Pilot Operator acting as the RPIC (Remote Pilot In Command) for at any given time.

OPERATIONAL SCENARIO DESCRIPTION

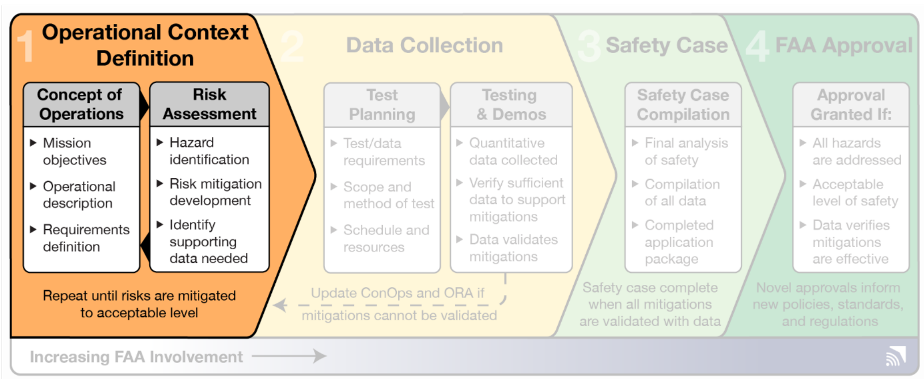
Field	Data Type	Input Method	Input Options	Relationships	Description	? Help
Mission Description	Text	Text entry	Custom		The operational scenario description provides an opportunity to summarize how the operation will be conducted and the expansions beyond typical operations that are necessary to authorize the flights.	
Type(s) of Operation	Button	Selectable	VLOS Remote VOs Successive VOs BVLOS OOP Night One to Many Other (text)	Carried forward to other phases		VLOS - Visual Line Of Sight VOs - Visual Observers BVLOS - Beyond Visual Line Of Sight OOP - Operations Over People One to Many - One GCS controlling/monitoring more than one UAS.

OPERATIONAL CONSIDERATIONS - GROUND BASED						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
Geographic Area Description	Text	Text entry	Custom	Carried forward to other phases	The location of where operations will occur and associated ground environment is often a critical aspect of operational flight approvals like Part 107 waivers and 49 USC § 44807 exemptions. Limitations on where a system may be operated can provide an effective tool to reduce exposure risk to persons and property on the ground.	The location of where operations will occur and associated ground environment. If will occur in secure areas or near critical infrastructure, this should be included in this section.
Boundaries	Coordinates	Upload Manual entry	GPS coordinates KML/KMZ Images			
Launch and Recovery Locations	Text	Upload Manual entry	GPS coordinates KML/KMZ Images Custom			
Proximity to Ground Based Non-Participating Persons, Structures, and Vehicles	Text	Text entry	Custom			Distance should be measured in feet/inches or meters.
Private Property Considerations	Text	Text entry	Custom			How will the RPIC maintain a stand-off distance (buffer zone) from non-participating property?
OPERATIONAL CONSIDERATIONS - AIRSPACE						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
Airspace Class	Text	Selectable	A, B, C, D, E, G	Carried forward to other phases	Similar to ground considerations, the exposure for air risk can often be impacted by the airspace environment the system will be operated in. This section also describes technology	List the most complex airspace to be entered assuming Class A is most complex and G is least.
Coordination with ATC	Text	Text entry	Custom			Describe strategic coordination with ATC, which likely occurs

					components, such as UTM and DAA, and coordination efforts with ATC that may become risk mitigations for certain air risk hazards.	prior to the operation. This includes direct notifications regarding upcoming operations, etc.
UAS Traffic Management	Text	Text entry	Custom			Describe how the RPIC will use UTM (Unmanned Traffic Management) technology to coordinate efforts.
Detect And Avoid (DAA)	Text	Text entry	Custom			How will the RPIC see and avoid or Detect And Avoid, all other aircraft when flying?
Proximity to Non-Participating Aircraft	Text	Text entry	Custom			Describe how non-participating aircraft are able to Detect And Avoid the sUA and know they must yield the right-of-way to the sUA or vice-versa.
METEOROLOGICAL CONDITIONS						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
Flight Rules	Text	Selectable	VFR SFR IFR	Carried forward to other phases	Describe the desired meteorological conditions during which are expected to be encountered during normal operations of the system.	VFR - Visual Flight Rules SFR - Special Flight Rules IFR - Instrument Flight Rules
Desired Meteorological Conditions	Text	Selectable	VMC IMC Day/Night Other			VMC - Visual Meteorological Conditions IMC - Instrument Meteorological Conditions Day - Morning Civil twilight to Evening Civil Twilight Night - Evening Civil Twilight to Morning Civil Twilight
Time of Operations	Text	Selectable	Custom			MM/DD/YYYY (UTC; Universal Time Coordinated). Begin and end times should be provided.
Equipage for Non-VMC	Text	Text entry	Custom			Please enter any equipment required as per safety case or

Field	Data Type	Input Method	Input Options	Relationships	Description	? Help
						regulation in order to operate in IMC conditions.
COMMUNICATIONS						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
ATC Communications	Text	Text entry	Custom	Carried forward to other phases	Communications with various groups can provide great strategic risk mitigations. How communication will be established and maintained with appropriate stakeholders should be described in sufficient detail.	Communications with ATC during operations, including broadcasting position over ATC radio frequencies.
General Aviation Comms	Text	Text entry	Custom			Communication methods with other aircraft in the vicinity.
Special Use Airspace/MTR	Text	Text entry	Custom			MTR - Military Training Routes
Internal Crew Comms	Text	Text entry	Custom			How will crew members communicate with one another?
Community Outreach and Notification	Text	Text entry	Custom			Will the community be notified regarding operations? If so, how? If not, why not?
SECURITY						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description**	**? Help**
C2 Link Security	Text	Text entry	Custom	Carried forward to other phases	The security section should describe how integrity of the C2 link will be maintained, if it is required for safe operation, against purposeful interruption. The physical security of the operator and equipment may also be necessary in certain circumstances to ensure safety.	How the integrity of the C2 (Command and Control) link will be maintained.
Physical	Text	Text entry	Custom			Physical security of operator and equipment.

Table 17: Help information for Phase 1b—Operational Risk Assessment. Help information is provided in the right-most column. Some text is diminished in size for space considerations.

<table>
<tr><th>PHASE OF PROCESS</th><th>DESCRIPTION OF DATA SCHEMA</th><th>? HELP</th></tr>
<tr><td>


</td><td>
The ORA lays the foundation for the data collection phase that will come next in the safety-case framework. The linkage of test data to risk mitigations provides the critical context necessary to interpret the data from test reports accurately.

The ORA data schema can be standardized in many areas and selectable menus may simplify data entry for many fields. However, there are certain fields that may be more difficult to enter, especially the "supporting data" field that may reference other FAA, industry, or scholarly published documents.

The lengthy and repetitive nature of ORAs makes them especially conducive to database systems. Virginia Tech has developed an Access database for this purpose, which was the inspiration for the FAA's prototype database of similar construct.

<table>
<tr><th colspan="6">Virginia Tech
UAS Operational Risk Matrix</th></tr>
<tr><th>Severity
Likelihood</th><th>Minimal</th><th>Minor</th><th>Major</th><th>Hazardous</th><th>Catastrophic</th></tr>
<tr><td>Frequent</td><td>5n</td><td>10a</td><td>15a</td><td>20a</td><td>25n</td></tr>
<tr><td>Probable</td><td>4a</td><td>8a</td><td>12a</td><td>16n</td><td>20b</td></tr>
<tr><td>Remote</td><td>3a</td><td>6a</td><td>9n</td><td>12b</td><td>15b</td></tr>
<tr><td>Ext Remote</td><td>2a</td><td>4b</td><td>6b</td><td>8b</td><td>14 * / 10b</td></tr>
<tr><td>Improbable</td><td>1n</td><td>2b</td><td>3b</td><td>4c</td><td>8c</td></tr>
<tr><td colspan="2" rowspan="3"></td><td colspan="2">High Risk 13.1-25.0</td><td colspan="2" rowspan="3">*Single Point or Common Cause Failures = Red / 14</td></tr>
<tr><td colspan="2">Medium Risk 7.1-13.0</td></tr>
<tr><td colspan="2">Low Risk 1.0-7.0</td></tr>
</table>
</td><td></td></tr>
</table>

METADATA						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description/Notes**	**? Help**
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects. However, it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.	Enter project identifier (used to track projects). Project identifiers must be unique to each project.
Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.	Enter title of project used to describe this project.
User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.	Enter user information, which generally is the name of the person leading entry of information and the organization/program.
Keywords	Text	Manual entry Radial buttons	Custom Predefined	Some may be carried from other phases	Keywords may include any number of relevant words. This can be used to identify unique aspects of the ORA. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of	Keywords may include any number of relevant words. These can be used to identify unique types of test methods, test articles, weather conditions, etc.

					common keywords, but should also allow for adding unique keywords that are not in a predefined list.	

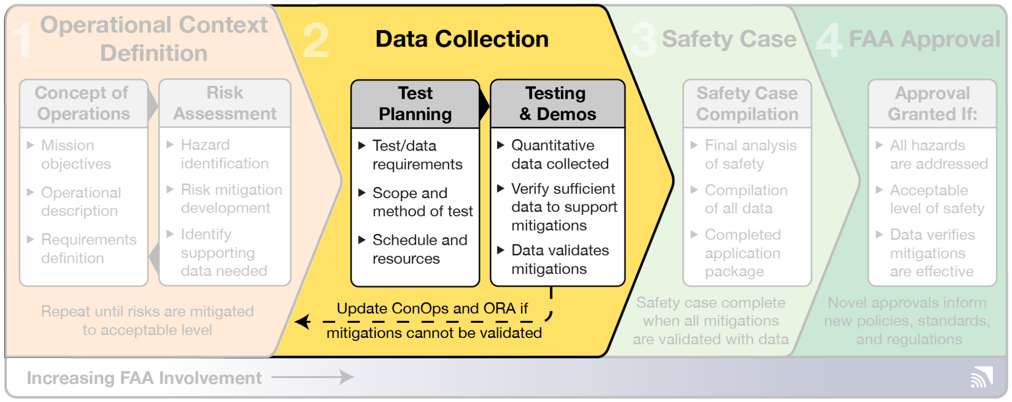
AIR RISK												
Unmitigated Risk Identification			**Mitigated Risk Identification**			**Prioritization of Risk Mitigations**			**Data Characteristics**			**? Help**
Hazard	**Pre-Mitigation Severity**	**Pre-Mitigation Likelihood**	**Mitigation**	**Post-Mitigation Severity**	**Post-Mitigation Likelihood**	**Criticality**	**Supporting Data**	**Validation Required?**	**Data Type**	**Input Method**	**Relationships**	Air Risk - Risk related to collision between a UAS and a manned aircraft or other UAS in the air.
Air Risk Hazard A NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	Safety Risk Management (SRM) is a key component of a Safety Management System (SMS). Guidance regarding SRM and SMS is provided in FAA Orders 8040.4B and 8000.369C. Guidance regarding

	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	SRM and UAS is provided in FAA Order 8040.6.
Air Risk Hazard *n+1* NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	
	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	
GROUND RISK												
Unmitigated Risk Identification			**Mitigated Risk Identification**			**Prioritization of Risk Mitigations**			**Data Characteristics**			**? Help**
Hazard	**Pre-Mitigation Severity**	**Pre-Mitigation Likelihood**	**Mitigation**	**Post-Mitigation Severity**	**Post-Mitigation Likelihood**	**Criticality**	**Supporting Data**	**Validation Required?**	**Data Type**	**Input Method**	**Relationships**	Ground Risk - Risk related to Collision between a UAS or its detached cargo and a person on the ground, or

Ground Risk Hazard A NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	moving vehicle. Safety Risk Management (SRM) is a key component of a Safety Management System (SMS). Guidance regarding SRM and SMS is provided in FAA Orders 8040.4B and 8000.369C. Guidance regarding SRM and UAS is provided in FAA Order 8040.6.
	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	

Ground Risk Hazard *n+1* NOTE: Single hazard may have multiple or numerous risks and associated mitigations	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	
	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Description of mitigation	Minimal Minor Major Hazardous Catastrophic	Improbable Ext. Remote Remote Probable Frequent	Primary Secondary Tertiary	Available existing supporting data	Yes No	Text	Text entry for descriptions and selectable lists for severity and likelihood	Carried forward to testing phase	

Table 18: Help information for Phase 2a—Test Planning. Help information is provided in the right-most column. Some text is diminished in size for space considerations.

PHASE OF PROCESS	DESCRIPTION OF DATA SCHEMA	? HELP
	All data provided in the CONOPS and ORA are carried over to the test planning section. This includes the configuration of the system, crew qualifications, and more. The ORA provides the context of the risk mitigations that will be tested. Differences from the CONOPS must be noted in the test plans and explained. There may be reasonable justifications for differences from the CONOPS, such as the addition of test equipment onto the aircraft, truth data sources, etc. DATA TYPE EXPECTED: Narrative format test plans that contain the information following the metadata section. The narrative format allows for flexibility in the method used to capture and report data, but also becomes challenging to query and search. To address this, a strong emphasis is placed on providing keywords in the metadata about the testing. Any query made by a user of the system should return the test report along with the full safety case file so that all contextual information is also provided with the test report.	

METADATA						
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description/Notes**	**? Help**
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects. However, it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.	Enter project identifier (used to track projects). Project identifiers must be unique to each project.
Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.	Enter title of project used to describe this project.
User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.	Enter user information, which generally is the name of the person leading entry of information and the organization/program.
Test Name	Text	Manual entry	Custom	Carried forward to test reports	Allow for custom naming of tests. However, it may be possible to create a standardized test name structure that helps identify tests that may be similar in nature across various users.	Enter name for test/test set.
Test Number	Text	Manual entry	Custom	Carried forward to test reports	Allow for custom numbering of tests.	Enter test number. This number generally represents a set of tests, but could represent an individual test.
Test Objective	Text	Manual entry	Custom	Carried forward to test reports	Custom input is important because test objectives may vary widely and therefore result in a list too long to possibly predefine.	Enter applicable test objectives.

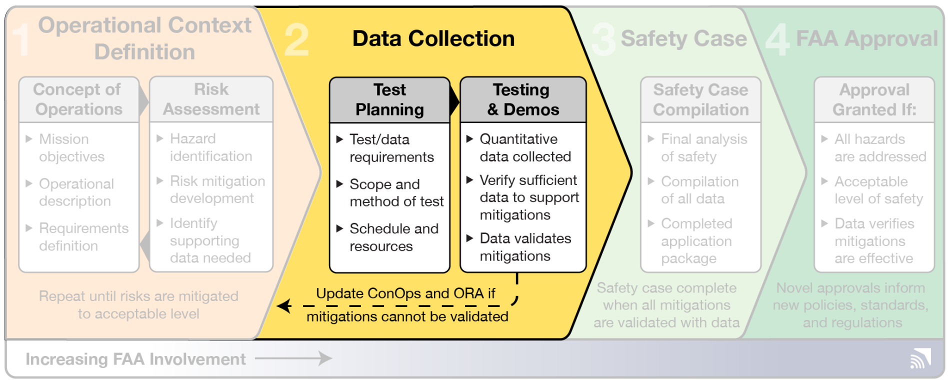
Hazard Category	Text	Drop down list	Mid-Air Collision Ground Collision – Persons Ground Collision – Property	Carried from ORA Carried forward to test reports	The input options listed here come from the UASTS OTA (Unmanned Aircraft System Test Site Other Transaction Agreement). An alternative would be to use just simply "Air Risk" and "Ground Risk".	Select the appropriate hazard category.
Specific Hazard	Text	Manual entry	Custom	Carried from ORA Carried forward to test reports	This is the specific hazard that could be realized and therefore must be mitigated against.	Specific hazard is also called hazard consequence. It is the bad consequence that results from a given hazard.
Risk Mitigation	Text	Manual entry	Custom	Carried from ORA Carried forward to test reports	This is the specific mitigation that has been put in place to prevent the hazard above from being realized.	A mitigation may be a change in design, a safety or warning device, or possibly training or development of a new procedure. A specific mitigation should reduce the likelihood or severity of the realized hazard.
Validation Method	Text	Drop down list or Radial buttons	Ground Test Flight Test Simulation Functional Demo Analysis	Carried forward to test reports	The basic method of validation is identified here. Demonstrations are distinguished from tests because they are designed to showcase a certain functionality, but perhaps without testing some statistically significant number of samples.	Please select the validation method. You may select more than one method.

Keywords	Text	Manual entry Radial buttons	Custom Predefined	Carried forward to test reports	Keywords may include any number of relevant words. This can be used to identify unique types of test methods, test articles, weather conditions, etc. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.	Keywords may include any number of relevant words. These can be used to identify unique types of test methods, test articles, weather conditions, etc.

NARRATIVE FORMAT (Example Contents)		**DISCUSSION**	**? HELP**
Test Requirements	**Description**	The Safety-Case Framework outlined in Task 1 of this project includes the following assessment: "A near-infinite number of possible data components could be listed, depending upon the question under investigation. Therefore, it is proposed that no complete list of data components can be defined, but instead the process should be utilized to identify, define, and collect the proper data for the question at hand." To this end, the team proposes that the exact format and contents of these narrative elements cannot be predefined, especially to maintain scalability of this process for things beyond just Part 107 waivers.	
Location Environmental Conditions Required Crewmember Qualifications Test Article Configuration Differences from CONOPS	The test requirements should fully explain the requirements that must be met in order to conduct the test. Specific attention should be paid to utilizing the properly configured test article operated by the appropriate crew in the necessary weather conditions.		Describe the requirements that must be met to conduct the test. These include the test article, the crew, weather conditions, etc.
Data Requirements	**Description**		
Position of RPIC Ownship position truth data Intruder position truth data Distance between ownship and intruder Closest point of approach	The data requirements section defines what data must be collected and how they will be collected. This is critical to ensuring that all necessary variables are collected and with sufficient accuracy. This list		Describe what data must be collected and how those data are collected.

	could be infinitely long, but might be standardized for certain tests.	However, it may be possible standardize the major components for specific scenarios (e.g. Part 107 waiverable provisions) to at least identify the topics that must be addressed and desired formats of the data contained therein. Additionally, industry consensus standards could be utilized to normalize the structure and organization of narrative documents.	
Required Resources	**Description**		
Test article components Test equipment Software Data acquisition devices	Identifies any specific hardware, software, and other resources that are needed to execute the tests. Specific configurations of each resource should be specified.		Identify specific hardware, software, and other resources required to execute tests (e.g., personnel). The specific configurations of each resource should be specified.
Test Execution	**Description**		
Test safety considerations Test dependencies Step-by-step instructions to complete test	Describes test-specific safety considerations and dependencies that must be met in order to continue testing. Instructions for completing the test should be sufficient to enable others to repeat the test accurately.		Provide instructions for completed the tests with enough detail that the description could be used to repeat the tests. Delineate specific safety considerations and dependencies.
Deliverables	**Description**		
Expected outputs of test Success criteria	Provides a preview of what the results of the test should look like so that real-time assessment of test validity and occur during test execution. Also predefines success criteria so that a satisfactory test can be determined quickly.		Describe expected outcome(s) of the tests. Define success criteria for testing to enable determination of successful test execution.

Table 19: Help information for Phase 2b—Test Data/Reports. Help information is provided in the right-most column. Some text is diminished in size for space considerations.

PHASE OF PROCESS	DESCRIPTION OF DATA SCHEMA	? HELP
	All data provided in the CONOPS and ORA are carried over to the test data section. This includes the configuration of the system, crew qualifications, and more. The ORA provides the context of the risk mitigations that will be tested. Differences from the CONOPS must be noted in the test plans and explained. There may be reasonable justifications for differences from the CONOPS, such as the addition of test equipment onto the aircraft, truth data sources, etc. DATA TYPE EXPECTED: Narrative-format test plans that contain the information following the metadata section. The narrative format allows for flexibility in the method used by to capture and report data, but also becomes challenging to query and search. To address this, the strong emphasis is made on providing keywords in the metadata about the testing. Any query made by a user of the system should return the test report along with the full safety case file so that all contextual information is also provided with the test report.	

METADATA						
Field	Data Type	Input Method	Input Options	Relationships	Description/Notes	? Help
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects. However, it may be possible to create a standardized project identifier structure	Enter project identifier (used to track projects). Project identifiers must be unique to each project.

					that helps identify projects that may be similar in nature across various users.	
Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.	Enter title of project used to describe this project.
User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.	Enter user information, which generally is the name of the person leading entry of information and the organization/program.
Test Name	Text	Manual entry	Custom	Carried from test plan	Allow for custom naming of tests. However, it may be possible to create a standardized test name structure that helps identify tests that may be similar in nature across various users.	Enter name for test/test set.
Test Number	Text	Manual entry	Custom	Carried from test plan	Allow for custom numbering of tests.	Enter test number. This number generally represents a set of tests, but could represent an individual test.
Test Objective	Text	Manual entry	Custom	Carried from test plan	Custom input is important because test objectives may vary widely and therefore result in a list too long to possibly predefine.	Enter applicable test objectives.

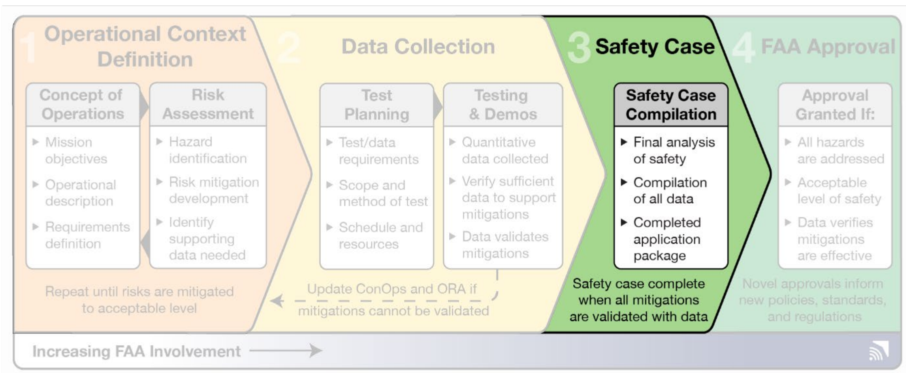
Hazard Category	Text	Drop down list	Mid-Air Collision Ground Collision – Persons Ground Collision – Property	Carried from test plan	The input options listed here come from the UASTS OTA. An alternative would be to use just simply "Air Risk" and "Ground Risk".	Select the appropriate hazard category.
Specific Hazard	Text	Manual entry	Custom	Carried from test plan	This is the specific hazard that could be realized and therefore must be mitigated against.	Specific hazard is also called hazard consequence. It is the bad consequence that results from a given hazard.
Risk Mitigation	Text	Manual entry	Custom	Carried from test plan	This is the specific mitigation that has been put in place to prevent the hazard above from being realized.	A mitigation may be a change in design, a safety or warning device, or possibly training or development of a new procedure. A specific mitigation should reduce the likelihood or severity of the realized hazard.
Validation Method	Text	Drop down list or Radial buttons	Ground Test Flight Test Simulation Functional Demo Analysis	Carried from test plan	The basic method of validation is identified here. Demonstrations are distinguished from tests because they are designed to showcase a certain functionality, but perhaps without testing some statistically significant number of samples.	Please select the validation method. You may select more than one method.

Keywords	Text	Manual entry Radial buttons	Custom Predefined	Carried from test plan	Keywords may include any number of relevant words. This can be used to identify unique types of test methods, test articles, weather conditions, etc. The keywords input is a critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.	Keywords may include any number of relevant words. These can be used to identify unique types of test methods, test articles, weather conditions, etc.

NARRATIVE FORMAT (Example Contents)		**DISCUSSION**	**? HELP**
Test Execution ("as tested")	**Description**	The test results should be simple evaluations of the test plans. Detailed test planning ensures that the method of the test closely aligns with the test plan and that the test results meet expectations of the test. Careful consideration must be given when there are differences in how the test was actually conducted, versus how it was planned. This is a common occurrence and may have negligible to significant impact on the results. Thus, differences must be tracked and explained in the final test report.	
Location Environmental Conditions Crewmember Qualifications Test Article Configuration Differences from Test Plan	Describes how the test was actually conducted. Differences or exceptions from the test plan must be clearly identified and explained. The effect of differences must be evaluated to ascertain if the test was executed in a manner that met the original objectives.		Describe how the test was conducted. This includes location, environmental conditions, crewmembers utilized (including qualifications), and test articles and configurations. Identify any differences from the test plan.
Test Data	**Description**		
Position of RPIC Ownship position truth data Intruder position truth data	Provide the actual test data from the testing, often data that has been analyzed will be primarily presented, but raw data may be included as supplementary data or as an		Provide test data. This generally involves presentation of analyzed

Distance between ownship and intruder Closest point of approach	appendix. Fields shown here are representative carry overs from the test plan.	The test reports identify whether or not the objectives were met at the end of the testing. The success criteria should have been established during the planning phase and, therefore, it is straightforward to determine if the risk mitigations proposed in the CONOPS/ORA were successful. If they were not successfully validated, then the framework requires that the CONOPS and ORA must be revisited to determine if there is a need to alter the operation or consider additional risk mitigations.	data. However, raw data can be provided.
Test Article ("as tested")	**Description**		
Test article components Test equipment Software Data acquisition devices	Identifies the test articles and their configuration in how they were actually tested. Differences from the test plan must be explained and justified.		Describe test articles and their configurations as they were utilized in the tests. Describe any differences relative to the test plan.
Results	**Description**		
Analysis of test data	Discusses how the data collected during the test meets, or does not meet, the objective of the test. Identifies if the test was conducted in an acceptable manner. Determines if the desired results were achieved and if the risk mitigation was validated.		Describe the results, including whether the tests were successfully executed and whether the risk mitigation was validated.

Table 20: Help information for Phase 3—Safety Case. Help information is provided in the right-most column. Some text is diminished in size for space considerations.

PHASE OF PROCESS	DESCRIPTION OF DATA SCHEMA	? HELP
	The safety case is a compilation of all the previous phases that is summarized to explain the overall safety of the operation. Therefore, this is typically a narrative document that references the previous phases in the safety case development process. A narrative document would be uploaded to the database with associated metadata that captures the context from previous phases. Similar to the other phases that contain that narrative documents (2a and 2b), there is a strong emphasis on keywords to aid querying of the documents. The metadata associated with all of the phases ensures that a query that returns a result from any single phase will also include the entirety of the safety case from initial CONOPS to final safety case.	

	METADATA					
Field	**Data Type**	**Input Method**	**Input Options**	**Relationships**	**Description/Notes**	**? Help**
Project Identifier	Text	Manual entry	Custom	Carried across all	Allow for custom identification of projects. However, it may be possible to create a standardized project identifier structure that helps identify projects that may be similar in nature across various users.	Enter project identifier (used to track projects). Project identifiers must be unique to each project.
Title of Project	Text	Manual entry	Custom	Carried across all	Allow users to custom name their projects for easy reference.	Enter title of project used to describe this project.

User	Text	Manual entry Drop down list?	Custom	Carried across all	Need to define what a user is. It could be an individual, company, program, or other.	Enter user information, which generally is the name of the person leading entry of information and the organization/program.
Keywords	Text	Manual entry Radial buttons	Custom Predefined	Some may be carried from other phases	Keywords may include any number of relevant words. This can be used to identify unique types of test methods, test articles, weather conditions, etc. The keywords input is critical to making the narrative format documents searchable in a meaningful way. The keywords section may contain a list of common keywords, but should also allow for adding unique keywords that are not in a predefined list.	Keywords may include any number of relevant words. These can be used to identify unique types of test methods, test articles, weather conditions, etc.

NARRATIVE FORMAT (Example Contents)		**DISCUSSION**	**? HELP**
Safety Case Elements	**Description**	As mentioned in the description of data schema above, the safety case is compilation of all of the previous phases of the safety-case framework. As such, much of the document will summarize previous documents and provide references regarding where to find information in the supporting documents. The actual safety case document is normally tremendously lengthy, as details are provided in the often lengthy reference documents. Instead, it	
Purpose	Describes why the safety case was sought, including how the expanded operation will benefit the organization, customers, and society.		Describe why this safety case was developed, including how the expanded operation benefits the organization, customers, and society.
Regulatory Authority	Identifies what regulatory authority the safety case is seeking to use for expanded operations (e.g., specific Part 107 waiverable provisions, 44807 exemptions, TC, etc.).		Identify the appropriate regulatory authority (Part 107, 44807, etc.).
Safety Case Method/Process	Explains the methodology employed during the development of the safety case.		Describe the approach used to develop the safety case.

CONOPS Summary	Summarizes the major components of the concept of operations, including the type of UAS and how it is operated and maintained.	should succinctly identify the approach taken to ensuring safety, explain the CONOPS, identify major hazards and risk mitigations, and then provide an assessment of the level of safety.	Summarize the CONOPS, including the type of UAS, the intended mission(s), etc.
ORA Summary	Summarizes the ORA process and expected final level of safety for the operation.		Summarize the ORA process and the expected final level of safety for the CONOPS/operation.
Primary Hazards	Describes the primary hazards identified for the operation and any unique features of those hazards.		Primary hazards are those hazards that, without mitigation strategies, have the greatest potential to cause harm or damage to others within the operating environment.
Mitigation Strategies	Provides a high-level overview of the mitigation strategies for the identified hazards. References the detailed ORA for the specifics of the risk mitigations.		The high-level overview is not intended to list all mitigation strategies but to highlight those strategies that significantly reduced the overall risk associated with the primary hazards of the operation.
Guiding Questions and Answers	Optional section that provides detailed answers to the FAA's Part 107 waiver guidance questions and where detailed information may be found in the supporting documents.		Provide detailed answers to the FAA Part 107 waiver guidance questions (if applicable).
Level of Safety Finding	Combines all the above information and the results from all testing to determine the ultimate level of safety established by the safety case.		Describe the ultimate level of safety established by the safety case. The ultimate level of safety is determined by identifying the highest risk determined by the safety case.

Appendices	CONOPS, ORA, Test Plans, and Test Report are often provided as appendices. Other supporting documents might include industry standards, technical papers from third parties, and other previous test results.		The Appendices may include evidence to support assumptions made within the safety case. This could range from training course outlines to research validating the lethality of a certain UAS if it were to hit a non-participant.

8 Conclusion

8.1 Overview

Execution of Unmanned Aircraft System (UAS) missions that are not permitted by existing regulations [e.g., 14 CFR (Code of Federal Regulations) Part 107] requires Federal Aviation Administration (FAA) approval of a safety case. While efforts are underway to establish standards that would eliminate the need for the safety case process, the variety of UAS missions and the pace at which standards are established result in safety case development being a common process that will enable UAS operations for many years to come. However, the characteristics of safety cases that are provided to the FAA vary significantly. Consequently, a framework that supports applicant safety case production and FAA analysis is needed.

In this effort (A19 Phase I), a safety case and an associated data schema has been developed. This process involved reviewing existing best practices and multiple FAA reviews (through formal tasks, monthly meetings, etc.). In addition, system software and hardware requirements were examined, a demonstration system was developed to elicit input from users regarding system efficacy, and training materials were developed. The efforts completed herein set the stage for follow-on efforts that will be directed at developing a prototype system (A19 Phase II), exercising the system, and developing the analysis system that will be used by the FAA to understand progress associated with integrating UAS into the NAS—including identification of gaps and research needs.

8.2 Scoping Questions

In the following, answers to the scoping questions are provided to the best of the ability of the A19 Phase I team. It is noted that more complete answers will be available once this research arc, including A19 Phase II and A24, is completed.

Question 1: *What are the key test objective types that must be captured in an ideal UAS risk-based framework?*

a. *What are the current test objective types?*

As indicated in the description of the data schema, the entry of test objective information is currently a custom, text-based input to support the wide-variety of test objectives that would be input into the system. However, the A19 Phase I team did identify five primary types of tests. It should be noted that more than one of these may be accomplished at the same time or during the same testing. The five primary types of tests are as follows:

1. System: This is hardware, software, or both. Generally, the objective is to illustrate that a system provides the desired functionality, although tests could also be conducted to evaluate reliability. This can be further decomposed into what types of functions the system supports (e.g., DAA, C2, airworthiness, flight management/execution, etc.). The challenge with continuing this type of break-out is it creates a possibly never-ending array of options. Thus, the A19 Phase I team has retained a flexible, text-based approach to input of test objectives.
2. Design: This type of test evaluates whether a system is properly designed. An example would be testing of a Human Machine Interface (HMI).
3. Procedure: This would typically be tests to determine if a procedure provides the desired amount of risk mitigation.
4. Crew Qualifications: Such tests would evaluate whether a defined set of qualifications enables performance of tasks at the desired level. Such tests could be categorized according to types of tasks (e.g., UA operation, communication, use of supporting systems, etc.).

5. Mission: Flights are conducted to evaluate whether UASs would function well for particular missions (e.g., linear inspection). Thus, while this category is a bit of an outlier in that the tests may not be conducted to evaluate a mitigation that enables integration into the NAS, it is a type of test that occurs.

b. *How are the objectives aligned with Safety Risk Management (SRM)/Safety Management System (SMS) practices?*

Test objectives are generally designed to evaluate the performance of a risk mitigation for a risk or risks identified in the SRM/ORA step (Phase 1b), and this is captured in the proposed data schema. Test objectives may not always be performed for this purpose, however. These include 'mission' types of tests and tests that are not executed as part of development of a safety case. Thus, the data collection system must be flexible enough to enable data entry for such tests.

c. *How do the objectives fit in an integrated safety case framework?*

This is illustrated in §s 2 and 3.

d. *How can these objectives be grouped in a logical manner?*

One potential grouping is provided above. As indicated, this can become very challenging as categorization of test objectives can result in a very large set of categories and subcategories. Multiple test objectives may be addressed during a single test. The A19 team recommends further development of test objective grouping, with a defined level beyond which categorization is halted. To enable this, use of 'other' as an input will be required.

e. *How can novel test objectives be incorporated in any developed framework and mapped to existing flights and data?*

The approach discussed in a. above is one means by which this could be accomplished. Given that these are novel test objectives, alignment of test objectives with test categories would be provided, although it is expected that at the final level of test objective classification the input would be 'other'. As the data collection system is expected to evolve, new test objective types could be integrated into the test objective schema.

f. *How can the test objective types be aligned with FAA research needs and functional areas?*

This is illustrated in §3 [Type(s) of Operation data element in Phase 1a]. As this data collection system is expected to evolve with testing and use, it can be modified to ensure desired alignment.

Question 2: *What are the key test data that must be captured in an integrated safety case framework?*

a. *What are the key outputs/statistics needed for the FAA to evaluate UAS capabilities, failure modes, and the effectiveness of potential safety mitigation strategies?*

This will be driven by the type of test. Given the variety of test types and subcategories within those, definition of a globally-applicable rule is daunting. Responses from different groups regarding the data they collect shows variation in what they consider important for a flight/mission in general as well as what is important for their system or operations evaluation. Evaluation of the performance of a DAA system, for instance, may require a different data set and thresholds than evaluation of an HMI. The different test or flight objectives by the users drive both the data collected and the quality of the data collected. Regardless, it is hard to envision successful evaluation occurring without quantification of results that includes uncertainty that is evaluated following agreed-upon methods.

b. *How does the CONOPS and risk management objectives affect the type of data to be collected?*

These generally drive the test objectives. The test objectives, in turn, define the data that must be collected. If a system is being tested, for instance, a functionality test set would characterize whether the system can perform at the desired level (e.g., detection range for a DAA system). On the other hand, a reliability test set would indicate how often a system performed its intended function (e.g., successful parachute deployment). Design, procedure, and crew qualification tests would commonly involve test data similar to reliability tests (e.g., determining how often something was successful). However, these test data would commonly be more granular than success/failure [e.g., Closet Point of Approach (CPA) data for DAA tests involving different levels crew training]. Mission types of tests are driven by the CONOP rather than the ORA associated with a safety case. Summary test data would generally be provided (which commonly could indicate success versus failure for the tests executed), but would be supported by specific data that support the summary data and provide insight into performance (e.g., timing data for DAA tasks).

c. *What is the minimum set of test data that captures enough specificity to answer technical questions but does not become too onerous to collect for the UAS operator?*

The recommended test data types are delineated in §3. This set of test data are recommended to ensure that the context of the tests is properly captured to enable interpretation of test results.

d. *How can proprietary data be collected and shared with the FAA more effectively?*

Proprietary data are challenging. While not incorporated in the current design, a means for flagging proprietary data would be useful to enable the FAA to properly protect those data. Such a tag could always accompany the data elements (including text-based documents) to ensure proper handling/sharing. Another option is for the data developer or a third party to 'scrub" the information to ensure only key applicable information is passed on. This would require additional time and effort to produce a "cleaner" product and also may have issues with not being provided as a raw unprocessed data set.

e. *How can proprietary information be secured but still accessible for analysis?*

Tagging of proprietary data would enable use within analysis. The proprietary tag would be utilized to manage proper protection/sharing of proprietary data. For instance, if a user does not have the proper credentials, that user would not have access to proprietary data. While this functionality is not in the current design, it could be added in A19 Phase II.

f. *How can these data be shared, queried, and analyzed most effectively?*

This question is central to the A24 effort. Provision of a detailed response is deferred to that effort.

Question 3: *How can the data collected by the FAA Test Sites inform a risk-based framework?*

a. *Of the suite of information that is currently being collected by the Test Sites, which data provides value for the FAA?*

The A19 Phase I team is not the FAA and, given the many ways in which the data could be used, it cannot definitively identify the most valuable data for all potential uses. However, The A19 Phase I team can delineate data that Test Sites provide and suggest uses for those data.

The Test Sites provide the following:

- Operational data via MLS.
- An ORA is provided for each project (separately from MLS).
- Flight planning Guide: This document defines Test Site policies and procedures. This is provided separately from MLS.
- Quarterly Reports: Submitted as a document—contain a summary of activities and lessons learned.

Thus, Test Sites do provide significant portions of the data associated with the proposed system herein. Moreover, when submitting a safety case, these would be tied together and would include test data. The system proposed herein provides a more systematic framework for this, although it is not designed for operational data (MLS).

MLS data are generally operational data and, as such, provide limited information regarding test objectives, test approach, and test results. However, examples of what those data can provide insight into include:

- Airworthiness: Information regarding aircraft type and flight times is provided. Cross-referencing of these with MLS accident and incident data can provide information regarding airworthiness.
- Failure modes: Types and rates of occurrences are provided. These could be utilized to generate statistics regarding failure modes.
- Types of Operations: MLS data include information regarding whether flights were conducted Line Of Sight (LOS) or BVLOS. Those data also include airspace class, flight rules (e.g., VFR), meteorological conditions (e.g., VMC), and whether flights occurred at night. Thus, information regarding advanced operations and operations in varying conditions can be used to understand progress with different types of operations.
- Impacts of payloads/supporting equipment: The AircraftNotes field provides information regarding the aircraft, including payload information. This information could be used to determine how often payloads have been used with different types of airframes and, thus, impacts on airworthiness.
- Operational characteristics associated with existing and emerging CONOPS: MLS data provide information regarding flight altitudes, airspace class, etc. These can be analyzed to infer characteristics associated with CONOPS.

b. What information is not being collected by the Test Sites, but should be?

Each Test Site collects and stores different data, and all provide the same subset of data back to the FAA that has been requested and is required by the FAA for the Test Sites to submit. The largest difference relative to that proposed herein involves test planning/objectives (Phase 2a) and test results (Phase 2b), which are expected to be provided by Test Sites if a safety case is submited. In addition, the data schema proposed herein involves collection of more CONOPS data fields as compared to, for instance, MLS.

c. What are the current practices for data collection at the Test Sites?

Every Test Site has a separate system to collect operational data. Summaries of some of this data are then translated into MLS. Some Tests Sites pay for data collection systems like DroneLogbook (DroneLogbook 2020), while others have developed in-house solutions.

Data are systematically collected using MLS, ORA submissions through the Knowledge Services Network (KSN), and quarterly reports. Test Sites also have their own approaches for collecting data to support the safety case development. The approach delineated herein represents a consensus for the Test Sites involved in A19 Phase I.

d. *What format/data definitions best serve a risk-based framework?*

The safety case framework and data schema serve as the response to this question.

e. *What are the economic and workload impacts of any proposed data collection changes on the Test Sites?*

One of the greatest sources of tension is the balance of acquiring information needed for safety case development while minimizing impact on the user. However, if a safety case is being developed, these data would have to be compiled anyway. Thus, relative to the situation where a safety case is being developed, the additional burden is estimated to be minimal. If a safety case is not being developed but data entry using the proposed system is desired, then this system could increase user burden. The compiled information differs in format for each Test Site, so if a uniform reporting structure or format is required, this would also increase the user burden.

Another source of tension is the cost of data collection. If the data are not supporting a safety case, then collection of some of the data can be extraneous to the mission of the Test Site client. Test Site client support is tailored to the client's needs. If that is the case, then the client generally does not wish to bear the cost of collection of those data. This, then, results in a lack of fiscal support for data collection.

Question 4: *What safety information is being collected by public and civil operators?*

a. *How do those data differ from what is being collected by the Test Sites?*

These types of operators range from individual Part 107 pilots to relatively large operations such as those associated with the UND John D. Odegard School of Aerospace Sciences (JDOSAS). The minimum data that are required for Part 107 operations, for instance, regards accidents (§107.9). However, these operators are not required to report number of hours on an airframe, etc. Many do track these, though, to ensure they are properly maintaining their systems. The UND JDOSAS, for instance, developed the Aviation Information Management System (AIMS; UND 2020), which is a system for tracking such information (and many other types of data relevant to flight education).

The accidents reporting requirement under Part 107 is similar to that for the Test Sites. However, the Test Sites also report incidents, which is any incident/mishap that results in an unsafe/abnormal operation. These are defined following standard provisions associated with COAs (e.g., FAA 2016), and include but are not limited to:

a) A malfunction or failure of the unmanned aircraft's on-board flight control system (including navigation)
b) A malfunction or failure of ground control station flight control hardware or software (other than loss of control link)
c) A power plant failure or malfunction

d) An in-flight fire
e) An aircraft collision involving another aircraft.
f) Any in-flight failure of the unmanned aircraft's electrical system requiring use of alternate or emergency power to complete the flight
g) A deviation from any provision contained in the COA
h) A deviation from an ATC clearance and/or Letter(s) of Agreement/Procedures

Thus, Test Sites generally collect information that are collected by public and civil operators. They also collect data regarding incidents, ORAs, operational data that go beyond hours on aircraft, etc. (including type of operation), and test data such as test objectives and results (in associated with safety cases).

b. *Is the information that must be reported by these operators sufficient to build a safety case for these operations?*

Generally, no. These operations operate within an existing rule set (e.g., Part 107), and thus are not designed to produce or collect data that would enable development of safety cases for new operations. However, information regarding airworthiness could be derived from the operational data that are collected (e.g., hours of operation for aircraft), which would likely require cross-referencing with accident reports. This would require that these operational data be submitted to the FAA.

c. *Does the FAA need to change the amount of data required from these operators to develop a robust safety-oriented data base?*

The A19 Phase I team believes that reporting of operational data (hours on aircraft, location of operations, etc.) would be very helpful. It also believes that reporting of incident data, like those data provided by Test Sites, would be very helpful. Efforts are currently underway to collect operational data through an ASSURE research project (UAS Parameters, Exceedances, Recording Rates for ASIAS; Aviation Safety Information Analysis and Sharing; ASSURE 2019). Such data will support development of a robust, safety-oriented data base. However, collection of test data as outlined herein will be critical to development of such a data base, especially for new and emerging operations. One constraint, of course, is the cost associated with data collection and reporting. If this cost is prohibitive, public and civil operators will not be supportive. Another challenge is some operators oppose any type of reporting.

8.3 Requirements

Requirements are provided in §1.3. These requirements are generally met, although not all are realized with A19 Phase I as they are to be addressed in subsequent efforts. One remaining area of ambiguity is alignment with FAA research domains and functional areas. The exact nature of this alignment is still being developed, and it is expected that this will be further defined in A19 Phase II and A24.

8.4 Lessons Learned

Key takeaways from this effort are:

- The need for a system such as the one designed herein is great, as many applicants do not understand how to build a safety case and the FAA needs a test data collection system to support their UAS research and development roadmap.
- A framework for developing safety cases can be organized into four primary steps:
    - Operational Context Definition

  - Data Collection
  - Safety Case
  - FAA Approval

  This proven approach provides a framework for developing a safety case regardless of the specific operational context, mitigation methods, etc.
- Best practices for safety case development are apparent. These have been collected and are presented in Appendix A for convenience.
- A review of existing data systems and team discussion underscored the challenges associated with data integrity. As this system is further developed, significant care will be required to ensure that data are entered in a consistent manner to ensure maximum utility for the FAA.
- One of the most challenging aspects to developing this system is definition of the data schema. The challenges associated with this include:
  - An incredibly large number of data elements could be included, as different information is relevant to different CONOPS, mitigations, etc.
  - Design of a system that provides the information needed to evaluate a safety case while also being as streamlined as possible for the user.
- Team members that evaluated the data schema presented herein, and who are experienced in test data collection and safety case development, determined that the data presented herein are needed for safety case development.
- Evaluators of the demonstration system definitely had preferences regarding layout, how information is presented, etc. As system development continues, close coordination with users will enable system utility.
- The hardware and software requirements for a demonstration system are modest, as the volumes of test data are much smaller than that for operational data.

8.5 Next Steps

Next steps are:

- Development of a production system that stores data.
- Evaluation and refinement of the production system.
- Exercising the production system using actual safety cases (preferably using advanced UAS operations).
- Evaluation of the host entity/location for the production system. Operation of such a system requires human resources to ensure proper operation, support system modifications, monitor data integrity, etc.
- Development of an analysis system that utilizes these data.

8.6 Disclaimer

It is important to reiterate that this report provides a suggested approach for compiling a safety case, with an associated data schema. While this research was supported by the FAA, it is important to underscore what was communicated in the NOTICE, including:

- The U.S. Government assumes no liability for the contents or use thereof.
- The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the funding agency.
- This document does not constitute FAA policy.

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Appendix A: Safety-Case Framework Best Practices

Best Practices that are highlighted throughout the description of the safety-case framework are collected here for convenience.

Table A1: Summary of safety-case framework best practices.

Phase	Best Practice	Description/Impact
Industry Drivers	Bounding the Operation	Description of: • Optimal result • Minimum viable product Sets thresholds for the safety case such that an unfeasible business case does not result.
Operational Context Definition (1)	Narrowing the Context	Process involves: • Beginning with a general CONOPS • Iteration that results in both a general and specific CONOPS. Starting general ensures that potential mitigations are not overlooked. Developing a specific CONOPS ensures that important details are captured.
	Prioritizing Risk Mitigations	Prioritizing risk mitigations enables identification of critical-path mitigations that generally require the most supporting data to validate.
Data Collection (2)	Identify Success Criteria Early	Identification of success criteria enables determination of whether tests are providing needed information. If tests are not providing the needed information, the approach should be modified (could include updating the operational context).
Safety Case (3)	Agree on Expected Outcomes	Alignment between outcomes supported by the data with FAA expectations is critical. Thus, desired outcomes should be identified early (Phase 1).

	Organization of Safety Case Matters	A safety case should: • Be easy to follow • Summarize the findings • Provide clear direction regarding where to look for details A concise and organized safety case will have a higher probability of success.
FAA Approval (4)	Post-Submission Meetings	A post-submission meeting can be utilized to: • Explain in detail the requested operation • Explain the information being provided • Explain how to navigate the information that is provided • Answer questions from FAA reviewers Such a meeting can greatly reduce misunderstandings that may arise.
Environmental Outcomes	Informing the Industry	Sharing of information, to the extent possible given restrictions associated with proprietary data, enables development of standards that serve the industry.