The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

Safety Risks and Mitigations for UAS Operations on and Around Airports: Final Report

March 4, 2024

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16. Abstract

The research described in this report is intended to identify and address the gaps in knowledge about the use of UAS on and around airport surfaces. This research includes: an assessment of the current state of on airport operations, the development of three UAS use cases, a safety risk assessment for the use cases, ground and flight testing to assess the use cases and the effectiveness of proposed hazard mitigation strategies, and a safety and operational assessment of ~20 years of large UAS operations by New Mexico State University (NMSU). The use cases selected were: an emergency response to an accident on a runway, a building inspection, and the operation of a large UAS from a runway. The key findings are: 1) the Safety Risk Analysis (SRA) developed for all use cases were very similar in the hazards identified and potential mitigation strategies, 2) the SRA procedures utilized by the research team were sufficient to obtain the required flight permissions, 3) the research team's internal pre-SRM Panel analysis of the materials submitted for the large UAS flight approval concluded that the materials submitted were sufficient for the FAA to evaluate the risk of the operation, and 4) the research team encountered several situations where the documentation or process to obtain flight approvals was not clear, and are detail in the docucment. The NMSU team's background, descriptions of operation experience, best practices, roles and responsibilities, and lessons learned provide a clear route to safe UAS integration in the airport environment. Recommendations from this research include: the development of better guidance for operators requesting UAS waivers, the integration of flight data into ATC systems to help ATC personnel obtain greater situational awareness to manage complex traffic operations between UAS and crewed aircraft, building or analyzing existing airports so GPS and electromagnetic interference can be identified or minimized for UAS operations, and using SRA documentation, develop a standard list of potential risks associated with flights on and around airports that include risks that must be addressed at a minimum for a waiver to be approved. This research showed that operators need clear guidance on what permissions must be obtained prior to flying a UAS on or around airport surfaces. The FAA should use ASSURE, UAS Test Sites, and other advanced UAS operators to develop flight approval check lists, disseminate successful risk management strategies, develop policies and procedures, change regulations, and or inform standards.

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ACUASI	Alaska Center for UAS Integration
ADS-B	Automatic Dependent Surveillance–Broadcast
AGL	Above Ground Level
ARFF	Airport Rescue and Firefighting
ARTCC	Air Route Traffic Control Centers
ASSURE	Alliance for System Safety through Research Excellence
ATC	Air Traffic Control
ATCT	Air Traffic Control Tower
ATM	Air Traffic Management
ATO	Air Traffic Organization
CCE	Corridor Control Environment
CFR	Code of Federal Regulations
CG	Center of Gravity
CONOPs	Concept of Operations
COA	Certificate of Authorization
DOD	Department of Defense
EP	External Pilot
FAA	Federal Aviation Administration
GCS	Ground Control Station
GPS	Global Positioning System
HAW	Hazard Analysis Worksheet
IP	Internal Pilot
ISRB	Independent Safety Review Board
KSU	Kansas State University
LOA	Letter of Agreement
MAC	Mid-Air Collision
MC	Mission Commander
NAS	National Airspace System
NMAC	Near Mid-Air Collision
NMSU	New Mexico State University
NMSU UAS FTS	New Mexico State University Unmanned Aircraft System Flight Test Site
NOTAM	Notice to Airmen
PIC	Pilot-In-Command
POC	Point of Contact
PRA	Probability Risk Assessment
ROFA	Runway Object Free Area
RPIC	Remote Pilot In Command
SAG	System Analysis Guide
SMS	Safety Management System
SOP	Standard Operating Procedure
SRA	Safety Risk Analysis
SRM	Safety Risk Management
UAF	University of Alaska Fairbanks
UAH	University of Alabama Huntsville
UAS	Unmanned Aircraft System

UND	University of North Dakota
VO	Visual Observer
WC	Well Clear
WSMR	White Sands Missile Range

EXECUTIVE SUMMARY

As airport personnel begin using small Unmanned Aircraft Systems (UAS) for safety and security and as large UAS operations increase at airports, there's a critical need for established processes to ensure their safe integration into the airport environment and the National Airspace System (NAS). This is vital because current gaps in understanding and regulations pose barriers to safety. This research aims to bridge these gaps through a comprehensive approach that includes reviewing existing literature, developing UAS use cases to explore these gaps, assessing these use cases with the Federal Aviation Administration's (FAA) Safety Risk Management (SRM) process, and conducting ground and flight tests. These tests not only evaluate the operational processes but also the effectiveness of strategies to mitigate hazards.

The literature review highlighted two major findings: current regulations do not maturely or robustly effectively govern UAS operations at airports and a lack of documented safety data for operations conducted around airports. To tackle this, the researchers collaborated with the FAA to select three use cases—an emergency runway response, a building inspection, and a large UAS operation from a runway—for thorough risk assessment and mitigation strategy development. ASSURE researcher findings from these assessments and tests revealed that while the safety risk analyses for all use cases shared similar hazards and mitigation strategies, there were also notable challenges in obtaining flight approvals due to unclear documentation and processes, necessitating high-level FAA intervention. Approval challenges centered on implementing new processes and not access.

Furthermore, the team's evaluation of nearly two decades of large UAS operations by New Mexico State University (NMSU) at a non-towered, general aviation airport underscored the importance of initiating safety measures with a risk-based assessment of the vehicle and its operations, extending through all flight phases and contingencies. This approach is crucial for the safe coexistence of UAS with crewed aviation.

Ground and flight testing also highlighted unexpected challenges, such as electromagnetic interference and the discovery that specific operational tactics, like quick differential braking on slippery surfaces, are vital for safe airport operations. These findings emphasize the unpredictability of on-airport operations and the necessity for real-time operational data to enhance communication and situational awareness among all stakeholders involved, including Air Traffic Control (ATC), remote pilots, and airport managers.

ASSURE recommends the FAA enhance guidance for UAS waiver requests, integrate flight data into ATC systems for improved situational awareness, and either develop or refine existing infrastructure to minimize Global Positioning System (GPS) and electromagnetic interference for UAS operations. Additionally, developing a standardized list of potential risks for flights around airports, based on safety risk assessment documentation, would streamline the waiver approval process. Collaborating with various stakeholders, including ASSURE, UAS Test Sites, and BEYOND sites, can help capture integration challenges, refine flight approval checklists, disseminate effective risk management strategies, and ultimately inform policy, procedural changes, regulatory adjustments, and standards development. This collaborative effort is essential

for advancing the safe integration of UAS into airport environments and the broader airspace system, ensuring a seamless transition towards more innovative and efficient aviation operations.

1 INTRODUCTION & BACKGROUND

There is a general lack of policies, procedures, or criteria for operating Unmanned Aircraft Systems (UAS) on and around the airport surface while aircraft operations are in progress. However, some airports are finding uses for UAS on and around their facilities and UAS manufacturers and operators are beginning to operate UAS, including large UAS, on and around airport surfaces as the technology matures. With this increase in UAS operations on and around airports, additional risk is evident and additional mitigation must be considered and implemented to ensure the safe, efficient, and effective use of UAS. The background for completing this research was the FAA's acknowledgment at the start of this effort that there were minimal published standards, guidance, or letters to support best practices for UAS operations on airports. This research, in parallel with other FAA advancements was focused on an independent look at this area to improve safety.

An Alliance for System Safety through Research Excellence (ASSURE) team, comprised of the University of Alaska Fairbanks (UAF), Kansas State University Polytechnic (KSU), New Mexico State University (NMSU), University of Alabama Huntsville (UAH), and University of North Dakota (UND), accepted the FAA charge of conducting research to identify what policies, procedures, safety analyses, and technologies are required to safely integrate UAS operations with airport operation and with manned aircraft operations on and around the same airport surfaces. As a part of the project, the team conducted ground and flight testing under the auspices of two FAA UAS Test Sites: the University of Alaska UAS Test Site and the NMSU UAS Flight Test Site (NMSU UAS FTS). All the universities and Test Sites involved in this project leveraged their pre-existing policies, procedures, and criteria for conducting UAS flight tests on and around airport surfaces to ensure the safety of the flight testing.

The proposed research was intended to answer the following research questions and any related questions that were developed through the research process:

- What are the representative use cases for UAS on and around airport surfaces?
- What level of communication/coordination is required between UAS operators, manned aircraft operators, airport managers, ATC, and other airport users/operators prior to and during UAS operations on and around airport surfaces?
- How do the varying size and capability of different UAS types impact these use cases? For example: 1) Do large UAS traversing the runway/taxiway surfaces require different air traffic services than smaller UAS? 2) How does UAS size impact the potential integration with or segregation of UAS operations from manned aircraft operations? and 3) How does the size of the UAS change how wake turbulence impacts its behavior?
- What are the impacts of different airspace classes and towered/non-towered airports on these use cases?
- What are the common risks for these representative use cases? What are the unique airspace-class/UAS-specific risks for each use case?
- What are the potential mitigations to identified risks to ensure safe operations for UAS?
- What airport infrastructure would assist in mitigating the hazards of operating UAS on and around airport surfaces?

- What airport policies and procedures would assist in mitigating the hazards of operating UAS on and around airport surfaces?
- How does FAA Order JO 7110.65 (ATC services are not provided to any UAS operating in the NAS at or below 500 ft Above Ground Level [AGL]) impact the use cases and limit potential hazard mitigations for operations on and around airport surfaces?
- What issues identified during the application of the FAA's Air Traffic Organization (ATO) Safety Management System (SMS) process and SRM process to the selected use cases should be used to inform potential changes to FAA regulations and industry standards?
- What lessons were learned from these representative use case demonstrations?
- What recommendations from the literature review, use case analysis, SRM process, and flight testing should be highlighted to inform airport operations and design when integrating UAS on and around airport surfaces?

The research consisted of the following tasks:

- Task 1: Literature Review
- Task 2: Propose other related potential areas of research
- Task 3: Identification of research shortfalls from the literature review, development of case studies, and define the overall concept and specific use cases for conducting operations on the airport surface
- Task 4: Using the FAA's ATO SRM process to identify the hazards and mitigations of the use cases
- Task 5: Detailed evaluation of three specific representative use cases
- Task 6: Ground and flight testing of these use cases

This final report summarizes the information gained during the research and provides recommendations for the policies, procedures, safety analyses, technologies, and future research needed to safely integrate UAS into the airport environment.

2 SUMMARY OF LITERATURE REVIEW FINDINGS

The purpose of the literature review, which was conducted between August 2020 and May 2021, was to identify the relevant research and documentation in the areas of UAS performance in and around airports. As a part of this review, the team explored a broad number of areas in an attempt to capture as many applications as possible and to best characterize the maturity of UAS operations on and around airports. Some applications were mature, some were nascent, and some were notionally noted as potential with little to no substantive published documentation. Over 125 separate documents were part of this literature review which included documents and guidance from the FAA (inputs fro UAS Integration at Airports, sUAS for On-Airport Applications, siting reports, spectrum office, etc.), National Academies of Sciences, private industry, technical papers, and more.

Listed below is a summary of the findings, observations, conclusions, and take-aways that the team used to inform the subsequent research efforts.

- The current regulatory language does not maturely or robustly address the use of UAS on or around an airport.

- The FAA has left many decisions up to the local air traffic management team including determining whether or not a UAS can enter or operate within the airspace and integrate safely in the airport environment. This was based on different local airport operational considerations.
- Review of the literature has shown that airport operators desire language to assist them in making those determinations. The industry is growing and this balance of operations in the NAS has not yet been achieved.
- Various ATO procedures, phraseology, and guidance do not provide clear direction for UAS operating at or below 400 ft AGL.
- ATC is not prohibited from providing services to UAS operators.
- The ATO has developed some procedures for notification for suspicious UAS activity, but little guidance is given for planned operations.
- UAS operators must use processes involving special waiver or authorization for the various operations close to or within the airport environment.
- The FAA has provided safety waiver guidelines as well as additional risk management guidance to these operators for use in preparing their waiver and authorization requests through FAA Advisory Circular 107-2A, FAA Order 8040.4b, 8040.6, and the ATO SMS manual.
- Commercial activity and airport managers who desire to improve efficiencies, safety, and effectiveness have sought approval to use UAS in multiple areas.
- Use cases are often not documented in technical detail; they are operationally led. Therefore, there is limited detailed documentation of processes, procedures, and results. (Note: this was valid at the time the literature review was completed, but FAAhas since provided additional online tools and information)
- Facility and asset management, parts delivery, and construction monitoring UAS use cases have been conducted, but there are no significant published details related to the parameters or the outcomes.
- Wildlife management and aircraft inspections UAS use cases have more documented occurrences showing the viability of the use of UAS.
- Although many state and federal agencies are conducting research, the research team found it difficult to get information regarding ongoing collaboration between agencies.
- SARP efforts are focused on production of a targeted end product. While there has been some coordination and interchange between the FAA and some state entities, there appears to be a gap in overall communication in regard to the various state and federal agencies coordinating their research efforts and sharing results.
- Several areas were identified that must be considered when flying UAS on and around airports. These areas of consideration include:
    1. Aircraft
    2. Concept of Operations (ConOps)
    3. Airport Infrastructure
    4. Airport Usage
    5. Air Traffic Management (ATM) and Operational Protocols

6. Communication Challenges and UAS Emergencies
7. Current and Future Airfield Responses to Non Authorized UAS Incursion Threats
8. Privacy and Societal Concerns

- Use of UAS on and around airports provides additional opportunity for cybersecurity threats, including UAS operators use of UAS for nefarious acts including collecting data that was being obtained for airport use. This is an area that does have research for general use cases, but does not have extensive research focused on operations on and around the airport. This will be important as the on and around airport UAS use cases increase.
- While there is data reflecting the various considerations or hazards related to UAS flight on and around airports, there is little safety assurance data from completed safety cases.
- UAS operations on and around airports have been overall limited due to operational barriers, the evolution of the industry, and limited approvals.
- There were a limited number of available and published peer-reviewed journal articles directly dedicated to UAS operations on and around airports.
- There were more non-peer reviewed technical articles and online published articles.
- The evolving nature of this research highlighted there were a few well documented applications, some conceptual applications noted, and a few with minimal to no documentation in the public domain.
- *Current Landscape of Unmanned Aircraft Systems at Airports* (2019) presents 16 separate UAS use case examples in a number of different areas.
- Many inspection elements for Code of Federal Regulations (CFR) Part 139 inspections/compliance (ex. fence line inspection, facility security, etc.) are addressed in the general literature with few specific references to on airport operations.
- Pavement, ramp/runway, and airfield inspections provided several documented applications with procedures and processes and are possibly mature enough that companies are performing these services commercially.
- Obstruction surveys using UAS have been conducted through case studies and proof of concept flights as recent as 2019. Obstacle surveys were used to assess ATC tower view assessment and runway approach paths, maintenance inspections, and to collect the imagery needed to capture and process runway obstacle identification using photogrammetry.

Overall, the documented use cases of UAS on and around airports that involve the airport, ATM, and the operator need more refined processes and procedures. While the literature review provided a resource on maturity of many operations, the literature available clearly did *not*:

- Identify the existing standards used prior to UAS use to meet the use case need.
- Reflect documentation regarding how UAS will meet or exceed the current standard for the given use case.
- Identify established metrics to be used to demonstrate an increase in efficiency, safety, or effectiveness by using a UAS to complete the given case on or around the airport.

This literature review, and the use cases therein, provides a foundation for continued research and advancements in using UAS on and around airports. It should be noted that some of the bullets identified above that served to inform subsequent research efforts were overtaken by time, and some have been addressed. No attempt is made here to address each of these items here since the bullets did serve as some of the foundational pieces for the subsequent research.

3 IDENTIFICATION OF RESEARCH SHORTFALLS AND DEVELOPMENT OF USE CASES

Tasks 2 (propose other related potential areas of research) and 3 (identification of research shortfalls from the literature review, development of case studies, and definition the overall concept and specific use cases for conducting operations on the airport surface) merged during the course of the project. The research team used the literature review to identify which use cases and aspects of operations could be researched to further FAA understanding of UAS operations on and around airports and validate UAS use on and around airports. In determining these use cases, the team worked closely with the program sponsor and subject matter experts to ensure the selected use cases did not duplicate research being conducted by the FAA's William J. Hughes Technical Center. This led the research team through an in-depth assessment of what research was being done and what was missing that satisfied the Task 2 purpose and led to the selection of three unique case studies that the team would use to develop the concept of operations for conducting operations on the airport surface (Task 3).

After an exhaustive examination of the types of UAS operations that could occur on and around airports and a determination of which of these types of operations could benefit the FAA and not duplicate current research, the research team, program sponsor, and subject matter experts decided on three use cases for this project. The three use cases and lead institutions for each use case were:

1. Large UAS operations - UAF and NMSU
2. Landside building inspections - UND
3. Emergency response - KSU.

The team wrote up each use case and provided them to the FAA for approval (see Appendix B for the Use Case #3 write-up as an example). The use cases all included the team members conducting or analyzing flight operations at their local airports (Fairbanks International Airport [AK], Grand Forks International Airport [ND], Las Cruces International Airport [NM], and Salina Regional Airport [KS]). The research team for this project included two FAA UAS Test Sites: the University of Alaska UAS Test Site and the New Mexico State University UAS Flight Test Site. All universities involved in this project have working relationships with one or more of these Test Sites. Additionally, all of these universities have developed their own policies, procedures, and criteria for conducting UAS flight tests on and around airport surfaces that were leveraged for this effort.

3.1 Use Case 1 - UAF and NMSU - Large UAS Flight in Airport Environment

UAF and NMSU conducted several large UAS flights in the Fairbanks International Airport (FAI, towered, Class D) and Nenana Municipal Airport (ENN, non-towered, Class G) environments, as shown in Figure 1.

Figure 1. Fairbanks International Airport (FAI) and Nenana Municipal Airport (ENN).

Fairbanks International Airport (FAI) has commercial services provided by Alaska Airlines, Delta Airlines, and seasonally United Airlines and other larger carriers, multiple regional passenger and air cargo carriers, and a large number of General Aviation aircraft. FAI possesses multiple runways including paved, gravel, and ski runways, as well as a float pond. Nenana Municipal airport (ENN) has no large commercial passenger carriers, but does have a significant number of General Aviation operations and some commercial air taxi operations. ENN has two paved runways and a float pond.

3.2 Use Case 2 – UND – Infrastructure Assessment – Landside

UND conducted UAS landside infrastructure assessments at Grand Forks International Airport (KGFK) in Grand Forks, ND. KGFK is a Class D airport with commercial services provided by Delta Airlines and a local fixed base operator and over 10,000 hours of flight training per month conducted by the University of North Dakota. KGFK has complex airspace with either North-South traffic or East-West traffic having four runways total. Also, there are 12 helipads and traffic patterns between the parallel runways. Figure 2 shows GFK and RDR.

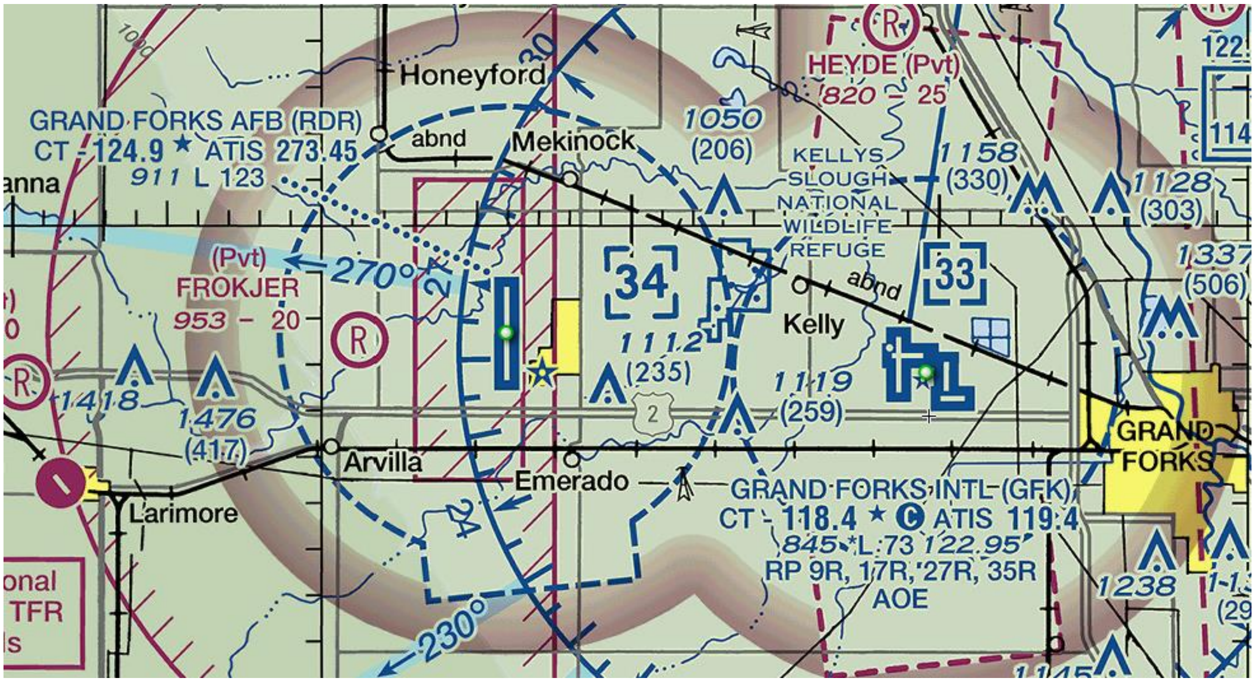

Figure 2. Grand Forks International Airport (GFK) and Grand Forks AFB (RDR).

All KGFK flights were conducted under less than 100ft and within 200ft laterally of the Remote Pilot In Command (RPIC). This was decided as part of the mitigation strategy, given the complexity of the airspace. The altitude restriction was a combination of discussions with the airport authority as well as the air traffic control manager. It was further validated by additional simulations using historical Automatic Dependent Surveillance–Broadcast (ADS-B) data and the use of SIMLAT. SIMLAT is a software tool that enables users to simulate the behavior of different aircraft types in a virtual environment while having the capability to manipulate the aircraft in real-time. These sources facilitated the determination of traffic density and helped identify additional risks associated with UAS operating on and around airports.

3.3 Use Case 3 – KSU – Emergency UAS Operations – Airside

KSU conducted an emergency response scenario at the Salina Regional Airport (KSLN) in conjunction with the Salina Airport Authority, Salina Airport Tower, Salina Airport Rescue and Firefighting (ARFF), and FAA representatives. KSLN is a Class D airport with commercial services provided by United Airlines, a local fixed-base operator, and flight training conducted by KSU.

During the literature review, many airports highlighted their desire to include UAS in airport emergency response and documentation. However, the airports did not have the processes and procedures to integrate UAS safely and routinely. To fill in the gaps identified in the literature review, KSU outlined the emergency response use case to present to the Salina Airport Authority. The KSU team worked closely with the KSLN Air Traffic Control Tower Manager to develop the ConOp. After settling on mitigations, the request went to the FAA's Mission Support Services (AJV). From there, they looped in Air Traffic Services (AJT). This use case was documented and approved by the these groups noted before engagement with the Salina Airport Authority. The emergency response use case intended to simulate a gear-up landing on an active runway to document the process of how ARFF would utilize the system to increase their ability to identify persons from the aircraft, monitor any fire resulting from the crash, and locate debris that may impact ARFFs ability to get to the crash and or persons from the aircraft.

As provided in Appendix B, all KSLN flights were conducted under 200 ft above ground level and the RPIC contacted the KSLN Tower 30 minutes prior to the flight and upon completion of the flight. The RPIC was also accompanied by a KSLN ARFF representative throughout the exercise.

4 EVALUATE USE CASES THROUGH AN SMS PANEL

After determining that the risks and potential mitigations for all three use cases were very similar and after a discussion with the sponsors, the research team decided to meet the SMS panel review on October 4, 2022, using all of the safety analyses done in support of a pre-existing Certificate of Authorization (COA) received by UAF 2022-WSA-10342 (Appendix D) and considering applicable hazards outlined in "Grand Forks International Airport – Safety Assessment for Infrastructure Assessment (Appendix C). The COA includes operations at FAI. The safety analysis documentation considered in the SMS panel review included all of the forms submitted into the FAA's COA Application Processing System, previous hazard matrices calculations for the UAF SeaHunter large drone, letters of agreement, memoranda of agreement, the actual COA, and other associated documents. The research team conducted an internal analysis of the documentation. A UAS Hazard Analysis Worksheet included the following elements:

- Hazard #
- Hazard Description
- Causes
- System State
- Existing Control or Requirement
- Possible Effect
- Severity/Rationale
- Likelihood/Rational
- Current /Initial Risk
- Recommended Safety Requirements
- Predicted Residual Risk (in terms of severity and likelihood – for 5X5 matrix)

The hazards assessed included the following:

- Loss of UAS Command and Control Link
- Loss of navigational control
- Propulsion System Failure
- Observer loses visual contact with UA
- UA Fly Away
- Lost comms between UA PIC and ATC
- Lost comms between PIC and observers
- Loss of Link with Tracking Antenna
- Mid-Air Collision
- Unknown Winds Aloft

- Low fuel prior to landing
- Frequency Interference
- Non-crew member interruption of flight crew
- Inadvertent IMC
- GCS electrical fire
- Crew fatigue

Using the standard 5 X 5 Likelihood and Severity risk matrix, each element was assessed for initial risk and residual risk after the "recommended safety requirements" were implemented. This resulting information was provided to the FAA during COA submission and identified two places where the language in the paperwork needed to be clarified. The hazards and potential mitigations identified in the internal walkthrough were consistent with those identified by all team members during their hazards analyses and SRA development.

5 GROUND AND FLIGHT TESTING

The research team conducted flight testing and analysis for the three select use cases to validate the communications between UAS operators, ATC, and other airport users/managers during UAS operations on and around the airport surfaces, the ability of the SMS process to identify and mitigate hazards prior to conducting the flight operations, and the effectiveness of the policies and procedures developed by the research team for operating on and around airport surfaces. The following sections describe the processes the team followed to receive flight permissions and conduct flight operations for the three use cases. It is worth noting that all of these individual testing activities were in process before the release of the October 26, 2022 FAA "Letter to Airport Sponsors about Policies and General Best Practices for UAS Activities On Airports" in which provided FAA "information about types of sUAS activities, considerations for proposed on airport sUAS operations, and resources to enhance operational safety and situational awareness for the related activities."

5.1 Working with Airport Authorities

5.1.1 KSU Airport Emergency Response

An initial meeting with a representative from the Salina Airport Authority, the Salina Control Tower, and the Salina ARFF was scheduled for March 23rd, 2022, to discuss their interest in participating in a flight test or demonstration for the emergency response use case. The intended Concept Of Operations (CONOPs) was briefed, and the following questions were asked:

- If someone wants to conduct UAS operations, what information do you ask from them?
    - What are your questions regarding the CONOP?
    - What are your questions regarding our experience?
    - Other than FAA approval to fly, are there any current safety standards regarding UAS that are expected to maintain?
- Does ARFF, or anyone else at Salina airport, currently use or want to use UAS for emergency response?
- Are there any current standards for conducting this Operation without a UAS? (Consider, can we accomplish this in a UAS and get the results the airport would need?)
- What are the current barriers to using UAS at the airport, including the barriers for ARFF?

All parties from the Salina Airport were interested in participating and wanted to be kept in the loop for all steps KSU would take to complete this demonstration. Once the Salina airport officials were on board, the CONOP was edited based on their revisions, and a safety risk management document was generated with UND to feed into the ATO process for large UAS and to help gain approval to operate at the Salina Airport.

5.1.2 UND Infrastructure Assessment – Landside

UND initially met with the KGFK airport authority and ATC representatives in regard to conducting UAS operations for landside operations and building inspections. In the initial meeting, the following questions were discussed:

1. Do you require insurance? If so, what?
2. Minimum flight experience for UAS operators?
3. How do their operations impact your Emergency Contingency plan for UAS?
4. Any Standard hazards or risks that you require they identify how they will mitigate?
5. Notification process for other vendors on the field?
6. Other than FAA approval to fly, are there any current safety standards regarding UAS that we are expected to maintain?

In relation to UAS operations for landside operations and building inspections (landside):

7. What periodic activities do you currently do?
8. Roof Replacement
    a. Wear and Tear?
    b. Damage assessment?
    c. Other?
9. For each of the possible activities listed, what are the current standards for conducting this activity without a UAS?

From this discussion, the UND team began conducting various scenarios for simulations to help identify possible hazards and risks associated with flying UAS for landside operations and building inspections. The resulting SRA document, described in the previous section and Appendix C, fed into the ATO process for UAF's large UAS operation and helped the UND team gain flight approval to operate at Grand Forks International airport.

5.1.3 UAF Large UAS Operations at Fairbanks International Airport

Integration of large UAS into airport operations at a large busy international airport was a process that took time and had multiple steps to ensure safe non-interfering operations. The section below details the chronological process of engagement, steps, and progress toward the actual flights. There is value in understanding the steps, processes, challenges, details, interfaces and exchange that were required to get to approval. The timeline below documents the elements. Documenting this process has value in that approval processes go through many different unforeseen steps. A milestone summary of these elements is included at the end of this section to provide overview and for clarity.

The UAF team formally began its effort to get permission to fly a large UAS (~300-450 lbs) from the airport surface of FAI in 2017. Up to that point, the UAF team members were participating in General Aviation meetings, talking informally with members of the FAI airport management, giving presentations on Alaska Center for UAS Integration's (ACUASI's) operations around the US and in other countries, and otherwise being active participants in the aviation community in Fairbanks.

In 2017, the Runway Safety Program Manager for the FAA's Alaskan Region saw a presentation in which the Director of ACUASI stated a desire to fly large UAS from FAI. He contacted the Director to discuss what would be needed to advance that goal and get the first steps in motion by including UAS in the FAA Alaska Region FY18 Runway Safety Plan. Some of the initial questions about operating on a runway included:

- In preparation to someday operate from a controlled runway, how will UAS pilots receive 'ATC' experience training?
- What do you envision the Runway Safety Program can do for you?

In June 2018, ACUASI opened a conversation with FAI Tower and submitted a COA request that included airspace permissions to operate from FAI to Circle, Alaska. This was immediately followed by ACUASI formally contacting the FAI Airport Manager about the potential for ACUASI to conduct operations at the airport. The first response from the FAI Airport Manger was, "I'm hearing good things about BLOS and UAF this week. What can we do to get ACUASI on the field at FAI soon?" This response exemplifies the interaction between FAI and the UAF team; the airport is a huge supporter of UAS integration at FAI.

In 2019, these runway safety questions from the Runway Safety Program team progressed to ACUASI being included in and providing assistance with input to the next iteration of the Runway Safety Plan:

- "One of the Runway Safety Program's action items for 2019 is working with ACUASI in developing policies and procedures for safely integrating UAS operations into Alaska airports. We are seeking to identify what technologies, runway marking, runway lights, cameras and signage would be needed at airports where UAS and manned aircraft operate jointly and eventually simultaneously."

On September 19, 2019, after multiple meetings with airport management, stakeholders, Fairbanks Tower, and others, UAF and FAI signed a Memorandum of Agreement (Appendix E) specifying how UAF could operate large UAS on and around the FAI airport surfaces.

UAF received the COA (2018-WSA01162 COA) for operations on May 1, 2020, but the COVID-19 pandemic and previous commitments in Canada prevented the UAF team from conducting the first flights at FAI during 2020 and the first half of 2021.

In August 2021, UAF was ready to fly its first flights at FAI using the DRS Sentry HP UAS. In preparation for the flights, UAF sent the COA and MOA to FAI personnel for forwarding to the FAI Air Traffic Control Tower (ATCT). The ATCT personnel caught a fact in the COA that the UAF team had missed: the COA required a Letter of Agreement (LOA) between ATCT and UAF in addition to the MOA between FAI and UAF. UAF and FAI ATCT quickly drafted a LOA and submitted it for approval. The LOA was not approved in time for Fall 2021 flights, so the team planned for a Spring 2022 flight.

During the fall of 2021, the UAF team answered multiple questions about the COA that were more about airspace in the COA area beyond the FAI Class D airspace, such as whether the team would fly in a Military Special Use Airspaces while they were active, and where the lost link points were on a map along the route to Circle, etc., than about operations at FAI. Additionally, the UAF team needed to renew the FAI to Circle COA, but the lack of the LOA held up the COA renewal. After much back and forth, the LOA process stopped due to FAA personnel raising the need for an environmental review and refusing to move the LOA forward in spite of it having the approval of the local ATCT, FAA Alaska Region leadership, etc. After raising questions on April 17, 2022, about this requirement with UAF's FAA BEYOND Program Manager, who had been trying to discover where the LOA was in the process, FAA leadership was able to determine where the hang-up was and break the LOA free.

Once the LOA was moving, UAF and ATCT personnel were able to agree to the content of the LOA, the FAA conducted a Safety Risk Management Panel for the operations, and the LOA was sent to Western Service Area for a review and approval. After Western Service Area approved the LOA (Appendix F), FAI ATCT had two weeks for training how to coordinate with the UAS team. On May 20, 2022, the LOA went into effect and the first flight of the Sentry UAS occurred on May 22, 2022.

The research team then geared up for a second set of large UAS operations from FAI. These operations were flights of the UAF Griffon Aerospace Outlaw SeaHunter (16' wingspan, 299 lbs maximum takeoff weight, twin engine) from FAI to ENN, a distance of approximately 40 miles. This set of flights allowed the research team to look at airport operations under two types of airport conditions: one large towered Class D (FAI) airport and a non-towered Class G (ENN) airport.

The UAF team told FAI ATCT and airport personnel that they would mount and test a forward-looking camera to SeaHunter prior to operating at FAI to ensure flight safety. The hope was that the team would be able to test the camera at ENN during high speed taxi testing in October 2022 and then quickly move the operations to FAI before snow fell. Unfortunately, snow did fall and the SeaHunter proved that an aircraft without differential braking was not suitable for operations on a slippery runway. This delayed SeaHunter operations until spring. The unexpected and delayed paving of the ENN runway delayed the operations until August 2023.

The SeaHunter conducted its first successful flight between FAI and ENN on Aug 2, 2023. However, before the team could repeat the flight from FAI to ENN and the return flight to FAI, an FAA employee examining the new pavement on the Nenana runway raised questions about where the Ground Control Station (GCS) was located. The GCS needed to be in the Taxiway Safety Area because the Runway Object Free Area (ROFA) was not cleared and the team needed radio line of sight for ground operations. This started a discussion about what permitting was required beyond the approval of the airport manager to be at that location.

The UAF team, its BEYOND Program Manager and associated subject matter experts, and personnel from multiple lines of business inside the FAA went back and forth over the next month about how the placement of the GCS impacted airport operations and what paperwork was needed to ensure all airport users could safely operate at the airport. The UAF and FAA resolved all of the questions through discussion and submitted FAA Form 7460 (Notice of Proposed Construction or Alteration) to allow their GCS to be placed in the Taxiway Safety Area. The taxiway was closed during operations to ensure safety and a ground Notice to Airmen (NOTAM) was implemented before operations commenced. UAF then resumed operations with flights to and then to and from ENN on September 7th and 8th, 2023.

Below is a general listing of the steps and a few considerations in the process.

- Early engagement with all stakeholders and approval authorities with one goal to get permission to fly a large UAS (~300-450 lbs) from a busy towered airport
- COA development and application
- Integration with airport to incorporate all UAS operations within the Runway Safety Program and airport operations. Focus on the development of policies and procedures for safely integrating UAS operations into the airports, identify what technologies, runway marking, runway lights, cameras and signage would be needed at airports where UAS and manned aircraft operate jointly and eventually simultaneously.
- Development and signing of a MOU between UAS flight team and the airport (Airport and Tower)
- Development and signing of a Letter of Agreement between ATCT and flight entity
- Addressing delays due to external impacts such as COVID-19
- Confirmation that all required paperwork for the operations is in hand and that all parties agree before operations begin.
- Training on how to coordinate between ATCT and the UAS team.
- Flight ready for operations on towered airports
- Additional steps for approval of for airport operations under two types of airport conditions: one large towered Class D airport and a non-towered Class G airport.
- Operations at the non-towered Class G airport considerations included
    - Installation of forward-looking camera on the UAS to ensure flight safety
    - UAS aircraft without differential braking were not suitable for operations on a snowy/slippery runway
    - Ground Control Station (GCS) location approval and permitting should consider location of all equipment, line of site comms, local airport approval, and any required permitting from the FAA (ex. FAA Form 7460 – Notice of Proposed Construction or Alteration)
    - Closing taxiway during operations to ensure safety and issuing a ground Notice to Airmen (NOTAM)

5.2 Flight Approvals

5.2.1 Dronezone Approvals for KSU and UND sUAS Flights

To receive a sUAS COA, KSU submitted the CONOP to DroneZone on August 2nd, 2022. The team received notification on August 5th, 2022, from the FAA processor that in order for UAS operations to occur over movement areas, it had to be closed with a NOTAM. Thus, deploying from ARFF to a scene would require a NOTAM. An alert 3 was discussed to close the airport until the determination could be made of what could be opened, and this decision would be up to the AJT to review. This Alert 3 would be in lieu of the NOTAM closure allowing the UAS to deploy from ARFF. The team suggested including an authorization that has a special provision with wording such as, "operations allowed only during an Alert 3 call, unless a NOTAM is filed at least 24 hours in advance." This would not only allow for the demonstration to be conducted with a NOTAM posted but also serve as a template for future airports hoping to conduct real-world operations in the future during a call and for training purposes. On August 12th, 2022, the KSU team received notification that the FAA was still reviewing the DroneZone application.

On August 18th, 2022, KSU received notification that the FAA had a meeting to review the application, but it got pushed up to Headquarters for review, and the team was told to stand by.

On September 1, 2022, UND submitted a COA request for KGFK. On September 7th, 2022, the FAA pulled the UND DroneZone application since both applications were for the same project in order for both FAA Points of Contact (POCs) to review the applications jointly. On September 13th, 2022, the FAA requested the A31 projects POC contact from our team for more information on the project, and the information was given.

On September 22, 2022, the KSU team contacted the FAA for any updates and suggested submitting a new authorization for a one-day demonstration only with a NOTAM in place to streamline the process. The FAA POC suggested that the A31 project lead touch base with the OSG Manager. On September 26, 2022, the FAA POC notified KSU that he was now taking over the UND application as well and would be in touch soon with an update. The POC also asked if the original timeframe through 12/31/2022 was sufficient; KSU requested a new end date of 12/31/2023. While the goal was to only fly once, getting an end date this far out would be great to show for the research that the goal would be long term implementation. On Sept 28, 2022, UND COA request was approved. UND COA 2022-P107-CSA-19247 was marked effective from October 1, 2022 to December 31, 2022. On October 17th, 2022, the FAA POC touched base to see if the KSU team had heard anything from the Salina airport manager regarding the operation. The DroneZone application request was set to expire on October 31, 2022, and to keep the process going, KSU would need to resubmit an application.

Based on the feedback from the FAA, KSU requested a meeting with the FAA POC for the DroneZone application, along with the participating members from the Salina Airport Authority, Salina Control Tower, and ARFF to discuss a new path forward for the demonstration. It was suggested that KSU only apply for a one-day demonstration application in which the area of Operation within the airport would be NOTAM closed during the demonstration. The timeframe for the application is to be reduced from one year to a one-week period to allow for the scheduling of the event. The FAA also suggested that researchers lower the operating altitude to no higher than 200 feet AGL. Based on this feedback, KSU revised the CONOP and resubmitted it to DroneZone on October 25th, 2022, and received approval on November 10th, 2022. The COA would be effective from December 5th, 2022, to December 9th, 2022. The demonstration was scheduled for December 7th, 2022.

5.2.2 COA Approval for UAF Flights

The UAF team used three separate COAs to conduct the flights performed during this project. As described in a previous section, UAF went through a multi-year process to obtain the COA for FAI (2022-WSA-10342-COA Appendix D). The ENN COA (2021-WSA-9404-COA, Appendix G) was easier to obtain through the normal COA Application Processing System since the airport is a non-towered Class G airport and the operations have visual observers at the airport to spot airport traffic. The COA covering the flight path between the airports is 2023-WSA-10406-COA and it was more difficult to obtain because it required chase planes and transitioning out of the FAI Class D airspace. The challenge with the ENN GCS highlighted the need to have ground NOTAMs in addition to airspace NOTAM depending on the situation at an airport.

5.3 The Flights

The UND, KSU, and UAF teams all submitted their flight test cards for approval prior to the flights and the FAA Program Managers greenlighted the flights.

5.3.1 KSU Airport Emergency Response

The KSU team received approval to fly their emergency response demonstration on November 10th, 2022. The successful demonstration occurred December 7th, 2022.

Below is the order of events for the day of the demonstration on December 7th, 2022.

- Issue NOTAM closing west side airfield November 30, 2022, for exercise on December 7, 2022.
- 11:00 West side airfield closed.
- 11:10 ARFF/Maintenance set up fuselage and debris at the intersection of 12 and 18.
- 12:30 ARFF personnel assigned to KSU escort KSU to Helipad 3.
- 1300 Tower Tones out simulated alert 4.
    - ARFF receives alert information and responds to the simulated crash site in ARFF #1.
    - KSU receives alert information and responds to the site.
- 1301 ARFF #4 responds to the simulated crash site.
- 1302 UAS arrives at the site and relays information to ARFF #1 via ARFF stationed with KSU.
- 1303 ARFF #1 arrives at the simulated crash site and applies water.
- 1305 ARFF #4 arrives at the simulated crash site and assists ARFF #1.
- 1305 Operations simulates closing affected areas via NOTAM, communications with the tower on ground stoppage, and runways and taxiways that can be used.
- 1330 End of exercise, remove fuselage and debris, inspect and cancel NOTAM.

5.3.2 UND Building Inspection

The UND team coordinated with Grand Forks International Airport and ATC to conduct several building inspection missions starting in October, 2022. The missions occurred safely and the team reviewed and revised their Safety Risk Analysis between flight campaigns to identify any unintended consequences with operation before conducting additional flights.

After flights, the SRA was reviewed and the team identified if all mitigations were accomplished, if there were any new risks, or unintended consequences identified. Throughout the various flights, only two risks not identified in the SRA document were noted. The first risk related to electromagnetic interference at the designed take-off location. Due to concrete/re-bar or other underground electrical interference, the aircraft was unable to take off, resulting in the team moving locations to safely take off. To mitigate this for future UAS operations, airport design may need to take into account power distribution and other sources of magnetic interference when dictating where UAS are allowed to fly or take off and land from. The second risk identified was that the GPS accuracy was less than expected. UND’s UAS on one flight lost over 50 ft from its assigned altitude. While the altitude didn't change on the UAS display, it could visually be seen as measurably lower than the assigned and altitude displayed. GPS coverage in the area was less than anticipated, causing significant error in actual altitude above ground. More research is needed to analyze GPS accuracy to mitigate UAS operations on and around airports. GPS accuracies tend to be less near buildings and at lower altitudes. Care must also be taken when considering emergency landing areas. Choosing an emergency landing area during preflight preparation must consider the GPS coverage and accuracy. Lack of preplanning could result in compounding emergencies resulting in greater risk.

It was further identified that while proper authorizations were conducted, two other UAS operations were also approved in the airport landside area. The only requirement UND had was to inform ATC within 15 minutes of flight. ATC did not seem to have real time location data on any of the other operators. Further integration of flight data into ATC systems could help ATC personnel of greater situational awareness to manage complex traffic operations between UAS and crewed aircraft, including the ability to better predict saturation levels during certain times of the day.

5.3.3 UAF Large UAS Flights

The UAF and NMSU teams conducted two sets of large drone operations at FAI during the course of this project. The first flight was a large drone operation using UAF's DRS Sentry HP (13' wingspan, 280 lbs dry weight) drone at Fairbanks International Airport (towered, Class D). The second set of flights included flights of the UAF Griffon Aerospace Outlaw SeaHunter (16' wingspan, 299 lbs maximum takeoff weight, twin engine) from FAI to the Nenana Municipal Airport (non-towered, Class G), a distance of approximately 40 miles. This allowed the research team to look at airport operations under two types of airport conditions: one large towered Class D (FAI) airport and a non-towered Class G (ENN) airport.

Prior to its first operations at FAI, the research team conducted taxi tests with FAI Air Traffic Control Tower personnel two days prior to the actual flight to ensure that everyone was comfortable with how the drone was going to operate on the airport surfaces prior to flight. Then, on May 22, 2022, and using the COA used for the SMS review panel, the Sentry flew for 32 minutes. The aircraft was completely integrated into the air traffic operating in the pattern at the airport. Fairbanks ATC personnel called the flight 'seamless' and a flight instructor operating in the pattern with the Sentry told everyone via Facebook that the Sentry acted like any other aircraft in terms of communications and flight behavior in the pattern.

The research team conducted the first successful SeaHunter flight between FAI and ENN on August 2, 2023. The hand-off of the radio line of sight links between GCSs at FAI and ENN in the middle of the flight went well and the aircraft landed successfully in ENN. The backup control of the aircraft through the Iridium link was maintained throughout the flight in case the hand-off did not go well. The team successfully completed another FAI-ENN flight on September 7, 2023 and quickly followed it by the FAI-ENN, land, ENN- FAI flight on September 8, 2023.

Figure 3. SeaHunter preparing to fly at Fairbanks International Airport.

The research team also took advantage of a project between Merlin and University of Alaska UAF Test Site that was funded by the FAA through the Qualified Commercial Entity program to gather additional information about UAS on-airport operations. In June 2023, Merlin flew a converted, autonomous Cessna Grand Caravan with a safety pilot and two software engineers on board, for 25 flights between Fairbanks and the Alaskan communities of Deadhorse, Ft. Yukon, Galena, Huslia, and Tanana. The autonomous plane landed on both paved and gravel runways at a variety of towered and non-towered airports with differing levels of ATC and support infrastructure.

6 OPERATION OF LARGE UAS AT NON-TOWERED AIRPORTS

The following sections provide background, descriptions of operation experience, best practices, and lessons learned from the almost 20-year history of NMSU's operations of large UAS from a non-towered General Aviation airport. NMSU has been flying since 2004 four different Aerostar aircraft from KLRU, the Las Cruces International Airport just west of Las Cruces, New Mexico (https://www.airnav.com/airport/KLRU). The UAS operations have been seamlessly integrated into the general aviation operations at KLRU. The following sections highlight applicable outcomes from these flights to help aid future large UAS flights from similar type airports.

6.1 KLRU, Las Cruces International Airport

The NMSU main operating area for large UAS is the Las Cruces International Airport (KLRU). The team has regularly performed operations of UAS that are greater than 55lbs under a Public COA. The COA used for these operations is ~15,000 mi^2 of airspace, surface to 18,000 ft MSL, that is roughly the southern western quarter of New Mexico as shown in Figure 4. The airspace includes areas west of the White Sands Missile Range (WSMR) and a number of other airspaces.

As can be seen in Figure 4, commercial air traffic flies north and south of the WSMR restricted airspace.

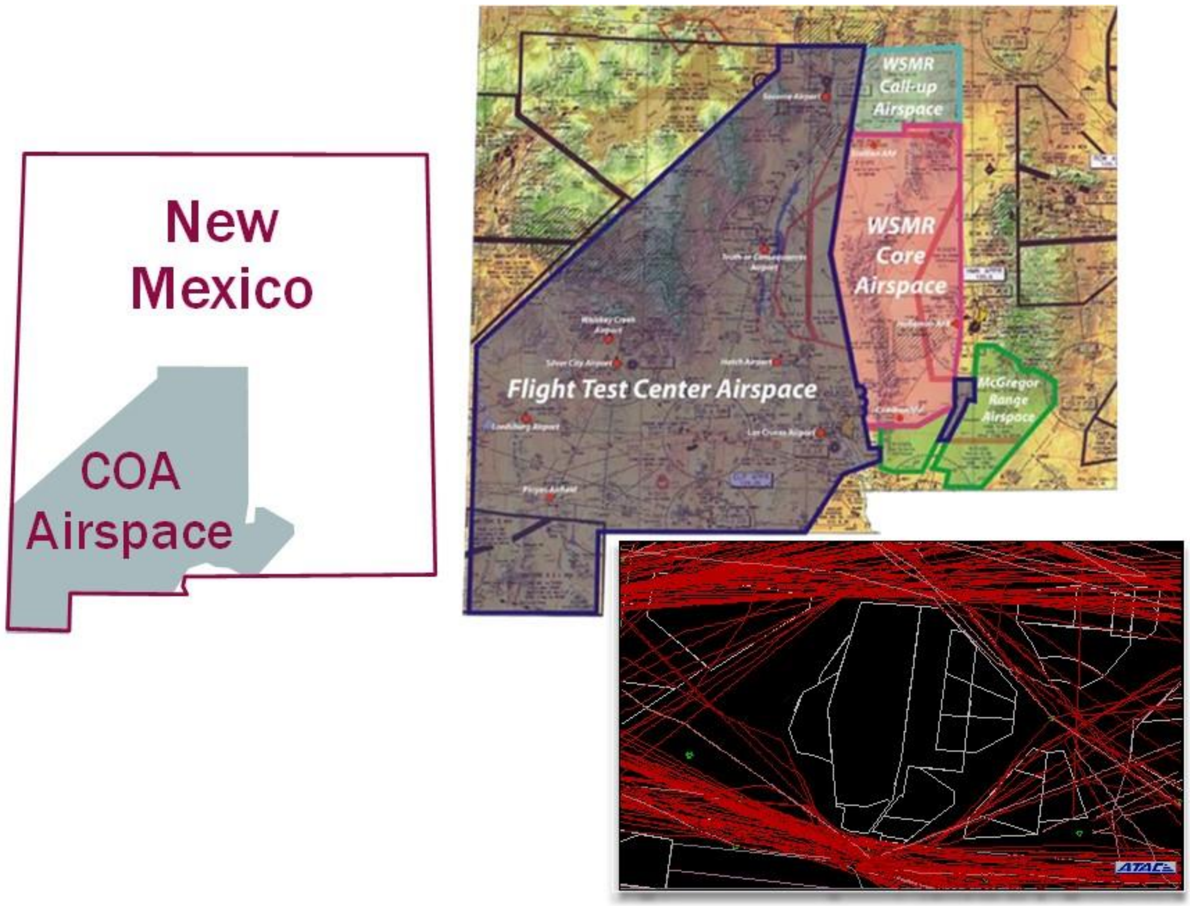

Figure 4. NMSU COA airspace and graphic of commercial air traffic patterns.

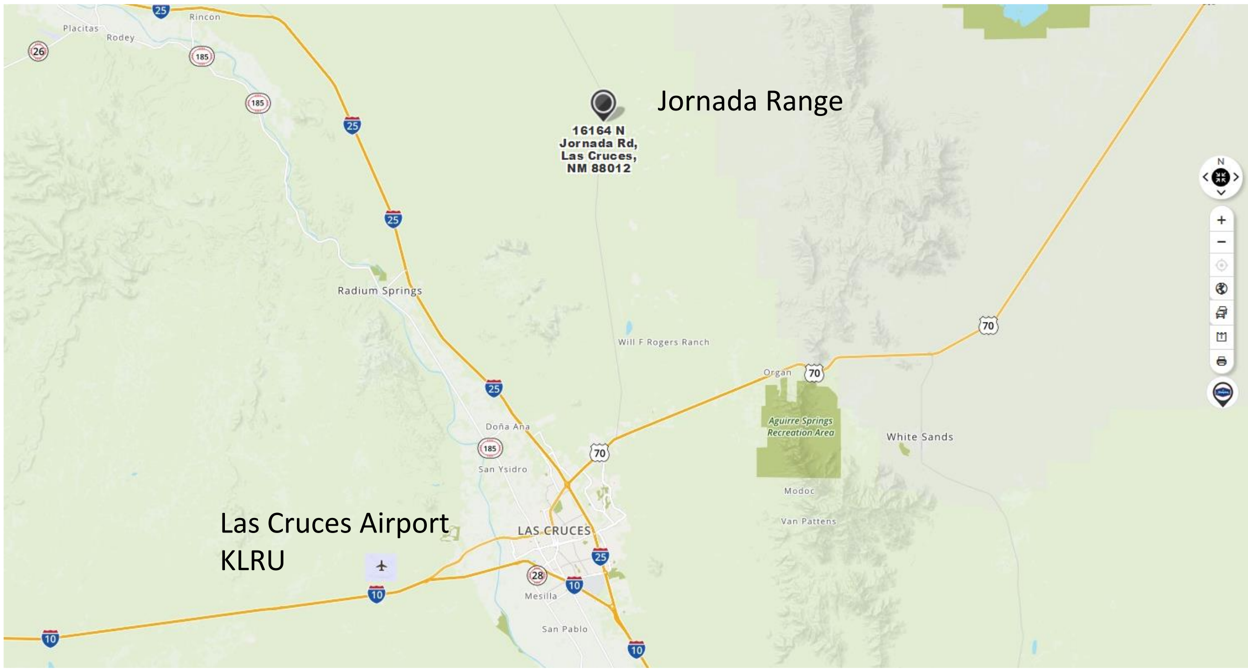

Figure 5. KLRU is located west of Las Cruces, NM.

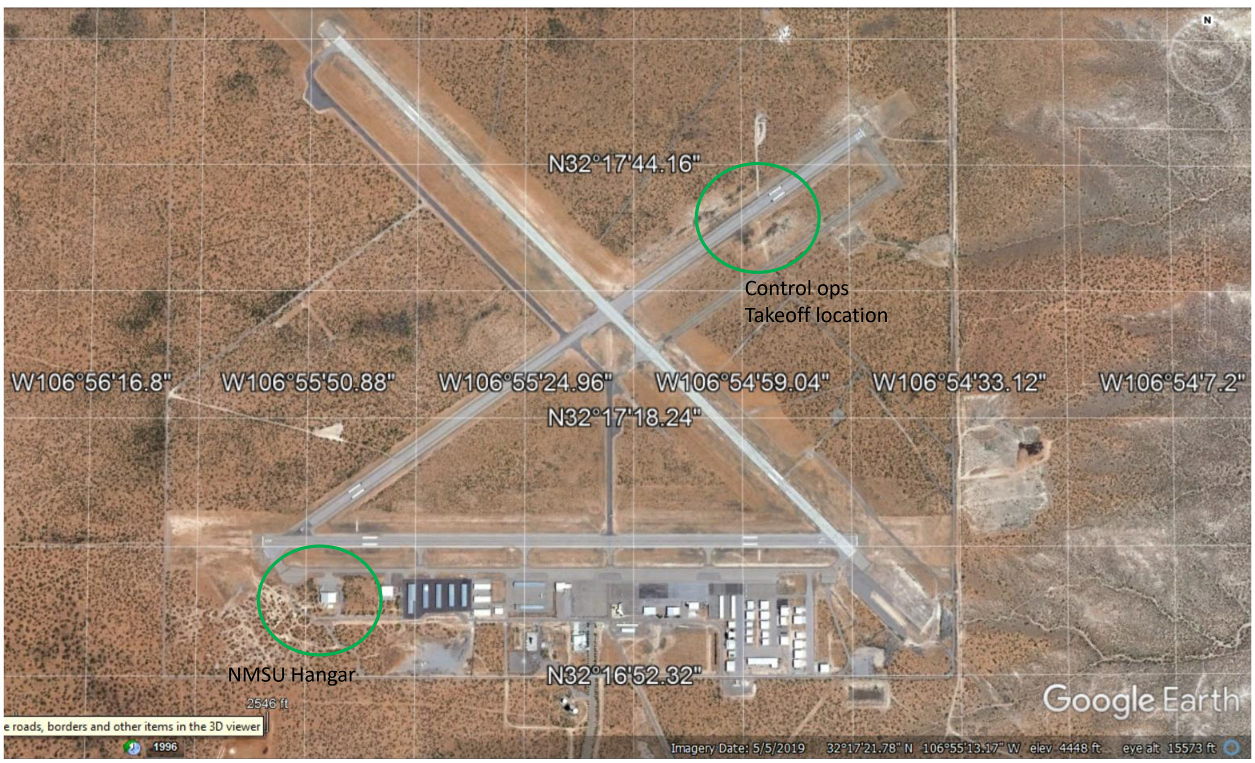

Figure 6. Overview of KLRU airport.

The NMSU large UAS operations are staged in the hanger in the lower left of Figure 6. The GCS trailer location can be seen in the upper right of the image. Takeoffs, flight control and landings are staged and operated from the GCS. Operations involve preparing aircraft and briefings at the hanger and then transport of people across the entire airport to the flight operations area. Arresting gear is placed on the runway ready for deployment. The aircraft is prepped off the runway and when ready to start is put into position on the runway for launch.

The runway used for these operations is Runway 4/22. It is an asphalt surface that is 7501 ft. x 105 ft. (2,286 x 32 m) located at 32-17.074570N 106-55.926100W at an elevation of 4,436.0 ft. It should be noted that the majority of the General Aviation air traffic is on the two other runways. There are ~106 aircraft based on the field including single engine airplanes (82), multi engine airplanes (10), jet airplanes, (2), helicopters (3), gliders airplanes (4), ultralights (1), and military aircraft (4). The airport averages ~101 aircraft operations per day with ~33% local general aviation, 29% transient general aviation, 28% military, and 10% air taxi.

Figure 7. NMSU hanger and GCS operations location for takeoffs and landings.

6.2 Aerostar UAV and Chase Plane

Most of NMSU's large UAS operations have employed the Israeli built Aerostar A and B. The B model, with a ~24.6 ft wingspan, is slightly larger than the A model. The Aerostar is a tactical class Unmanned Aircraft with twin booms, shoulder wing, and pusher engine configuration. They are equipped with a fixed main landing gear, arresting hook, and maneuverable nose gear. It can be equipped with an electro-optical payload, installed in the bottom of the fuselage center section, enables a full observation for effective surveillance missions. Images of the aircraft are shown in Figures 8 – 10 for reference.

Figure 8. Aerostar on the tarmac in the NMSU PSL hanger during a STEM outreach event.

Figure 9. Aerostar undergoing pre-flight checks before transport to the flight line.

Figure 10. Aerostar in flight.

The aircraft is made of composite materials, mainly carbon and fiberglass with epoxy resin. The construction is of a shell type, with reinforced bulkheads at the nose, mid wall in front of the payload, bulkheads at the front and back of the fuel tank, and a firewall at the aft compartment.

Core materials provide reinforcement at the loaded zones around the wing and landing gear attachment points. The fuselage is divided into four main compartments and provides maintenance access panels for all equipment elements.

1. Payload and equipment main compartment (from nose bulkhead to fuel tank bulkhead)
2. Power supply compartment
3. Aft compartment (from fuel tank to the firewall)
4. Engine compartment (aft of firewall)

Parameters and specification of the Aerostat B are shown in Table 1.

Table 1. Aerostar B Specifications.

Parameter	Specification
Performance	
Stall speed flaps up (Flight position)	42kts
Stall speed flaps 38° (Landing position)	38kts
Optimal climb speed	57-60 kts
Loiter speed	55kts
Dash speed	110 kts
Rate of climb	>700ft/min
Service ceiling	18000ft
Take-off distance	250m
Landing distance	90m (with arresting sys.)
Glide rate (no wind)	1:10m
Weight - incl. fuel (70L.) and payload	210 to 230kg
Endurance at 10,000ft.	12Hours
Loss Range - UHF	150km
Dimensions	
Wing span	7.51m
Total length	3.00m
Height	1.51m (with directional antenna)
Wing root chord	0.40m
Wing tip chord	0.25m

The UAS specifications are similar between the A and B Model Aerostar. The main changes are the wingspan, directional C-Band on the B model, and an omni C-Band only on the A model.

The general capabilities of this aircraft are a range from controlling station out to 150 km. Because of the need to fly a chase plane, flight altitudes are generally limited to 12,500 MSL or 13,999 MSL (30-minute limit for no oxygen for chase crew), 17,999 MSL (with oxygen for chase crew and appropriate Chase Aircraft). Speeds are generally 55-85 kts. The B model aircraft has a tail camera located on the right vertical stabilizer that displays a fisheye view of the UAS during flight. Additional general information about these aircraft is presented in Figure 11.

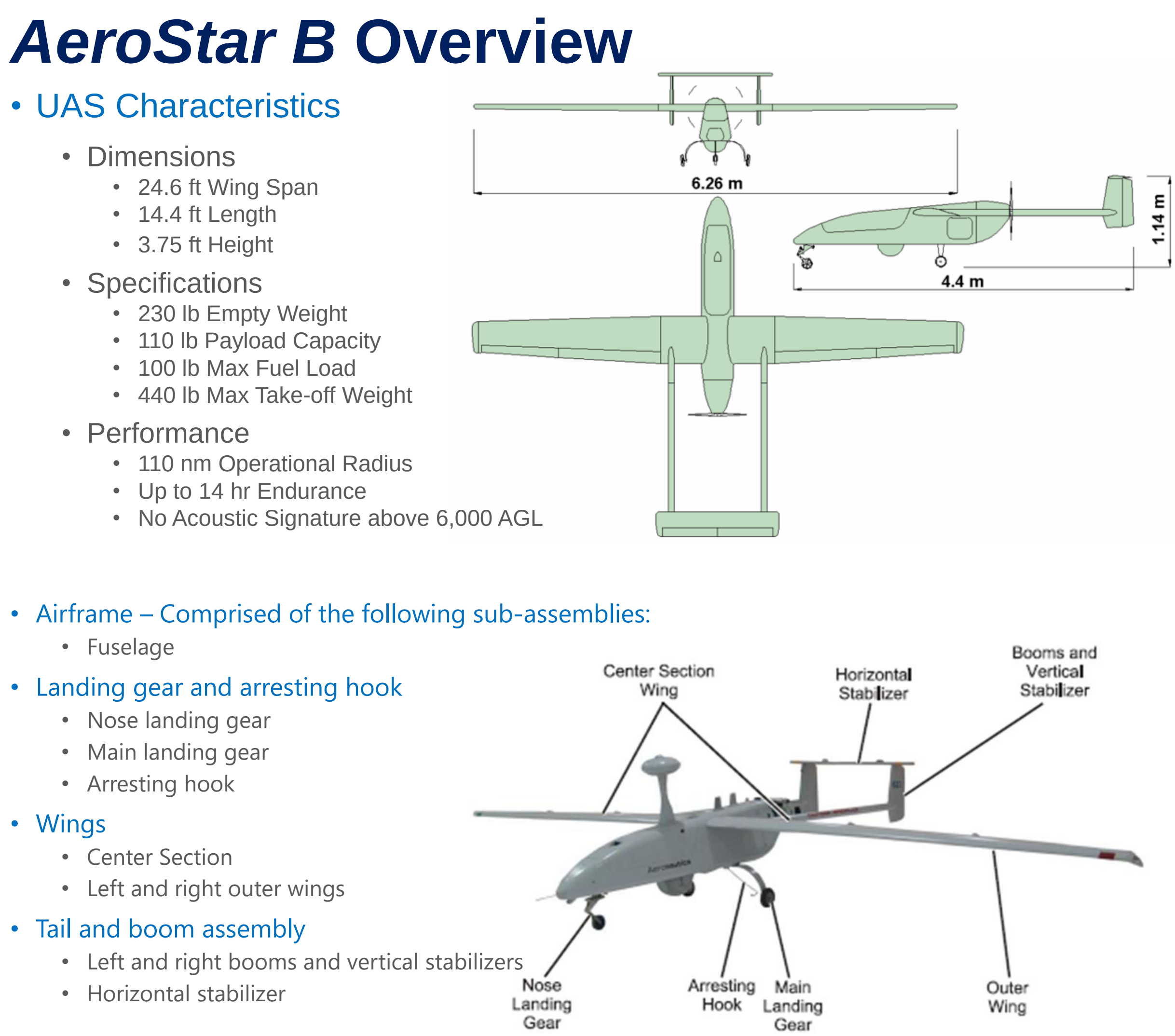

Figure 11. Aerostar B.

The ground control element includes control from either a Mission Control Station or Launch and Recovery System utilizing a C-Band Ground Data Terminal for primary up/downlink and an Omni ultra-high frequency antenna for secondary uplink. Remote video control is available using a Remote Payload Control Station via a separate ultra-high frequency uplink. Flight operations are quite complex and require seven to ten personnel depending on the required mission profile. Missions utilizes an External Pilot for takeoff and landing and an Internal Pilot for the mission duration. A typical flight crew makeup is shown in Figure 12.

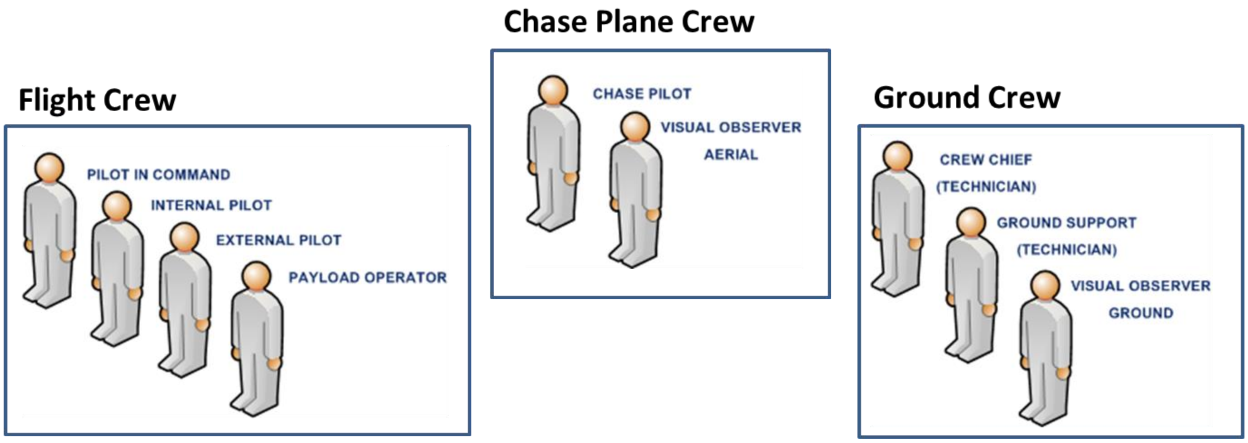

Figure 12. Typical flight crew for Aerostar operations.

Overview descriptions of the crew positions are as follows:

- Mission Commander: The mission commander serves as the on-site organizational manager and mission coordinator for UAS flights. He or she is knowledgeable of organizational and operational mission objectives and is the primary disseminator of information to both operational and outside personnel/organizations. They are knowledgeable and experienced with performing UAS operations, including traditional aviation operations, procedures, airspace, and regulations. They are the operations team lead for UAS flight operations as well as the ultimate organizational authority during flight operations.
- Internal Pilot (IP): The IP controls the UAS during flight outside of the visual range of the EP or when the EP is not required during flight inside the visual range of the EP. When the EP is flying, the IP is responsible for continuously monitoring the conditions of the UAS and providing feedback to the EP.
- External Pilot (EP): The EP directly controls the UAS from a point on the ground using remote flight controls within a direct line of sight. He/she utilizes this configuration to perform rolling takeoff and landing from the runway.
- Crew Chief: The crew chief is the primary crewmember organizationally responsible for the custody, physical security, and airworthiness of the UAS. He/She supervises other ground support personnel during maintenance and ground operations. He/she is responsible for ground support equipment.
- Ground Crew: He/she is responsible for performing ground support duties not directly associated with controlling the UAS that includes (but are not limited to) inspection, preparation, assembly/disassembly, physical launch and recovery of the UAS, fueling/de-fueling, and routine maintenance of the UAS, and associated ground support equipment.
- Observer: He/she serves as ground or aerial observer during flight operations. He/she is responsible to provide "see-and-avoid" capability to the flight crew.
- Chase Pilot: He/she flies the chase plane, responsible to provide safe separation from the UAS during chase operations and maintaining a position in a loose trail to give the observer an adequate view of the UAS and other traffic to provide "see-and-avoid" capability.

Safe operations require personnel to have the proper experience and qualifications. For the NMSU operations with large UAS, pilots must have a Part 91 Pilot Certificate and a 2nd Class FAA Medical. They are also required to have UAS specific training from the manufacturer/factory. Visual Observers must have completed the NMSU UAS Test Site Visual Observer training and have a state issued driver's license. Additional UAS specific training is required of the pilots for this aircraft. The NMSU UAS Test Site utilizes the manufacturer's training program to qualify Aerostar A and B personnel. Typical Internal Pilot training included 30 to 35 sorties for 25 hours. Typical External Pilot training included 20 half-scale sorties and 25 Aerostar B sorties. For operations, there are also imposed crew limitations as follows:

- Mission Commander: 12hrs in a 24hr period
- Internal Pilot: 8hr in a 24hr period
- External Pilot: 4hr in a 24hr period
- Ground Visual Observer: 12hrs in a 24hr period
- Chase Pilot: 8hr in a 24hr period
- Airborne Visual Observer: 8hr in a 24hr period
- Other Ground Support: 12hrs in a 24hr period

For beyond visual line of sight operation from the launch and recovery location, the NMSU team uses a Flight Design CTLS light sport aircraft owned and operated by NMSU UAS FTS as a chase plane. Information for this aircraft is provided in Table 2.

Table 2. CTLS.

The FD CTLS is a 2 seat Light sport aircraft.. The FD CTLS is designed for flight training and personal use. This aircraft will be flown as the intruder in A45 flight testing. *The image shown is not the actual aircraft.*

Wing Span	28 ft 2 inches	**Cruise Speed**	100 knots
Maximum Takeoff Weight	1320 lbs	**Operator**	NMSU UASFTS
Fuel Capacity	34 US gal	**GPS**	G296

6.3 Background on Large UAS Flight Operations by NMSU

The bulk of the NMSU large UAS operations were with the Aerostar aircraft. NMSU has used four different Aerostar platforms for these operations. These flights started in September of 2004 and were from various locations including Fallon, NV; Stallion at WSMR; NAWS at China Lake; Condron at WSMR; Playas, NM; Space Harbor at WSMR; and LRU in Las Cruces, NM. Flight logs for all 368 flights using the four different Aerostar platforms are summarized in Table 3.

Table 3. Flight history of NMSU Aerostar aircraft

Aircraft Tail Number	Number of Flights	Flight Time (hrs)
617	86	198.9
618	228	433.5
659	23	44.9
660	31	55.6
	368	732.9

The total number of flights from KLRU, Las Cruces, NM was 276 representing 75% of the total number of flights. Approximately 15.2% of the Aerostar flights were from towered airports (Fallon and China Lake). 84.8% of the large UAS operations completed by the New Mexico team were flights at non-towered airports. This gives a baseline of 312 Aerostar flights to draw upon for operational considerations and lessons learned for operations from non-towered airports.

In addition to flying the Aerostar, there have been a few other large UAS that have been flown from the Las Cruces International Airport (KLRU). These include the Dihedral Jet (1 flight), Vortex700 (3 flights), Bat 4 (6 flights between 2018 to 2020), SkyEye (1 flight), and V001 (3 flights). The BVM Jet also had 5 flights from the Playas Airfield (private airfield). Table 4 presents the statistics on these flights since 2016. There were additional flight operations of large UAS, specifically with the BAT4, that were not located at an un-towered airport, but in remote locations from a dirt airstrip in the middle of NM rangeland.

Table 4. Large UAS flights by the NMSU UAS FTS since 2016.

UAS	Number of Flights	Flight Date	Airfield
Aerostar	9	2/28/2023	KLRU
Dihedral Jet	1	12/14/2021	KLRU
Vortex700	1	3/31/2021	KLRU
Bat 4	1	9/3/2020	KLRU
Aerostar	3	7/20/2021	KLRU
Aerostar	6	12/2/2022	KLRU
Bat 4	1	11/21/2018	KLRU
Bat 4 and Vortex700	2	11/1/2018	KLRU
Bat4	3	10/8/2018	KLRU
Aerostar	7	8/26/2019	KLRU
SkyEye	1	11/17/2017	KLRU
BVM Jet	5	8/17/2017	Playas Airfield (Private)
Aerostar	1	6/5/2017	KLRU
Aerostar	2	4/3/2017	KLRU
V001	3	6/6/2017	KLRU
Aerostar	2	11/1/2016	KLRU
Total Flights	48 at Manned Airports		

6.4 NMSU UAS FTS Standard Operating Procedures

As noted in previous sections, the NMSU flight team has conducted ~330 flights of large UAS at un-towered airports. Each mission follows a standard flight operations flow. The NMSU UAS FTS Standard Operating Procedures (SOPs) for UAS operations are living documents that foster safe operation of UAS for all flight regimes including large UAS operations on airports. Lessons learned have been incorporated into these documents and SOPs. The NMSU UAS FTS organized its SOPs into four series to address distinct phases in the analysis, planning, and operations processes. The series include series-1) SOPs covering administrative matters; series-2) SOPs focused on the risk-based assessment process; series-3) SOPs covering flight operations; and series-4) SOPs addressing post-flight analysis. These are listed in Table 5.

Table 5. Standard Operating Procedures for the NMSU UAS Flight Test Site.

Phase	SOP Number	SOP Title
Administrative	1.1	Administration
Risk-based assessment process	2.1	Quick-Look Analysis
Risk-based assessment process	2.2	UAS FTC Web Site Access
Risk-based assessment process	2.3	Applicant Data Review
Risk-based assessment process	2.4	Safety Assessment
Risk-based assessment process	2.5	Technical and Operations Review
Risk-based assessment process	2.6	Independent Safety Review Board (ISRB)
Risk-based assessment process	2.7	Final Qualification
Risk-based assessment process	2.8	Final Inspection
Risk-based assessment process	2.9	Data Collection
Flight Operations	3.1	Flight Operations Planning
Flight Operations	3.2	Flight Readiness Review
Flight Operations	3.3	Airspace and Flight Coordination
Flight Operations	3.4	Flight Operations
Flight Operations	3.5	Pre-Mishap Plan
Flight Operations	3.6	Site Survey
Flight Operations	3.7	Uncontrolled Airports
Flight Operations	3.8	UAS Chase Aircraft Operations
Flight Operations	3.9	UAS Contingencies
Flight Operations	3.10	Spectrum
Post Flight Analysis	4.1	Post-Flight Analysis

Flight safety begins well before the actual flight operations. The risk-based assessment process noted above has multiple sequential steps. All of these are required before any flight operations of a large UAS. Short descriptions of what is included and what should be done before any large UAS operations is presented in the following section. There is much more information included in each of these SOPs but only the elements germane to operations at an un-towered airport are noted.

6.4.1 Risk-Based Assessment Process

Quick-Look Analysis – The NMSU UAS FTS collects and analyzes basic information to determine whether the UAS is a candidate to operate in the NAS. The quick-look analysis is intended to filter out those systems that present an unacceptable level of risk, or other requirements, before the parties involved invest resources in extensive technical and operational reviews. The UAS FTC collects a standardized set of information from each proponent for determining whether a UAS demonstrates the potential to meet the minimum system, operations, and administrative requirements established by UAS FTS and the FAA.

Collected information includes a description of the UAS such as aircraft dimensions, weight, speed range, altitude capability, engine type, fuel type, payload, control data link system, and launch and recovery methods. Descriptions of ground control system(s) and operator functions are provided. Desired flight operations to be conducted including the number of flights, timeframe, and previous flight history. Safety elements collected include the safety hazards to other airspace users, safety hazards to people and property on the ground including chemical, radiation, and explosive hazards. Any proprietary information is also identified up front. Key to determining if a large UAS can operate at an un-towered airport are the maturity of the systems as the included safety systems as follows:

- Maturity History
  - Flight Time (hours)
  - Takeoffs/Landings (number)
  - Power Plant (hours)
  - Communications Links (hours)
  - Navigation Systems/GPS (hours)
  - Transponder/IFF (hours)
  - Crew Experience (hours)
- System Safety
  - Return Home Software: Tested or Not Tested or N/A
  - Flight Termination System: Tested or Not Tested or N/A
  - Ballistic Recovery System: Tested or Not Tested or N/A

Applicant Data Review – After the review of the Quick-Look Analysis, the NMSU UAS FTS gathers the full set of information to perform a review. The proponent completes the System Analysis Guide (SAG) and a team of subject-matter experts is assembled to review the information and to obtain further information from the proponent if more data are needed to complete the analysis. The SAG contains requisite data on the UAS including:

- Aircraft/airframe and subsystems
- Command and control system/methods
- Failure management systems
- Flight operations (processes/procedures) and personnel
- Ground support equipment, requirements, and procedures

The review team members individually review the SAG in the areas of:

- UAS operations

- Aviation safety
- Aviation/UAS engineering
- Communications/spectrum analysis
- Aviation/UAS maintenance
- Contingency planning

An Initial Risk Assessment is prepared that addresses the following:

- Proposed flight operation location
- System strengths
- System weaknesses
- Safety considerations
- UA features findings
- GCS features findings
- Command and control findings
- Ground support equipment
- Other subsystems
- Basic flight operations/requirements (chase operations, etc.)
- Contingency planning

Safety Assessment – The Safety assessment has the ultimate goal to resolve areas of concern enabling the hazards to be mitigated to acceptable risk level. The NMSU UAS FTS team gathers all of the relevant information including:

- Copies of SAG with questions and answers
- Copies of attachments to the SAG
- Additional question and answers provided during the review
- Manuals and checklists (operations, maintenance, emergency procedures, and training as required)
- Any specific test plans
- Areas of concern document with priorities
- Hazard Analysis Worksheets (HAWs)
- Limitations and contingency plans
- Copies of the SOPs
- Copies of the COA
- Copies of the Cooperative Research and Development Agreement, if applicable
- Current FAA guidance

The proponent presents an informational briefing on their UAS. Proponent briefs on their UAS, should not be regurgitation of SAG, and include at minimum:

- Airframe and subsystems
- Autopilot
- Navigation
- Ground control system and subsystems
- Ground power support

- Communications subsystems
    - Command and control
    - Crew communications
- Software development, simulation, and testing
- Operations procedures/processes and crew resource management
- Emergency and contingency procedures
- Maintenance and continued airworthiness procedures, logs, and documentation
- Safety items and procedures
- HAWs and limitations
- Crew responsibilities and certifications
- Ground support equipment and procedures
- What support (if any) required from other groups including the NMSU UAS FTS team

Technical and Operations Review – A subject matter expert team is charged with assessing and documenting the hazards of the operation. The team compiles information related to the UAS flight operation and then assess the proposed operation with regard to the UAS, the proposed location, and the risks identified. HAWs are developed for each hazard. At a minimum, HAWs will be completed for the hazards of flyaway, loss of UAS control, loss of communications with the UAS, pilot/observer error, and unsafe ground operations. Risk assessment of the hazards is performed that look at all of the UAS systems and subsystems including the airframe, propulsion, avionics/navigation, safety systems, electrical systems, communication, command and control, and payloads.

Control measures are developed for the identified hazards and risks. The control measures and flight operations limitations are to reduce risk to an acceptable level of safety for other aircraft, personnel, and property. Contingency plans are also developed to cover any unforeseen circumstances in the best way possible. The review team establishes specific operating limitations to mitigate risks identified during the assessment and inspection phases.

Independent Safety Review Board (ISRB) – The ISRB is the culmination of the all of the risk-based steps. The ISRB will reach one of three findings:

- The UAS operation, as presented, appears safe and planning and preparations should proceed.
- Planning and preparations can proceed pending completion of minor mitigation measures to address specific safety issues.
- Further planning and preparations should not proceed until major modifications are made to accommodate serious safety concerns.

Final Qualification and Final Inspection – The bulk of the previous steps are "paper reviews." A final inspection of the actual flight hardware is required before flight to ensure safety. The NMSU UAS FTS personnel perform the following actions during the final inspection:

1. Conduct a visual inspection of the UAS airframe, fuel system, landing gear, control station(s), and engine. NMSU uses a very detailed, 72-point proprietary checklist for this inspection.
2. If a minimum or required equipment list exists, it will be checked for compliance.

3. Review UAS maintenance records and logbook entries for unresolved maintenance issues or recurring problems.
4. Inspect the condition of launch and landing systems and GCS.
5. Check the launch and landing areas, runways, and taxiways for damage or obstructions that could impact the safety of flight.
6. Review NOTAMS for new obstructions in the operating area, what frequency authorizations exist, and send the information/safety email.
7. Inspect the lost link/return-to-home location to verify that no buildings, vehicles, or equipment have been moved into the area since the original site survey. Confirm the capability to secure access roads and control foot traffic into the area if required. Lost link point(s) and flight termination points will also be review and checked.
8. Observation of the proponent crew during flight preparations is required to ensure that the crew is following their established procedures.

Data Collection – Data can be collected for multiple purposes including internal reporting and documentation, data collection for technical assessment, FAA reporting, and others. The NMSU UAS FTS records both non-flight specific reported data, as well as flight specific reported data. Each of these is outlined below and is shown as a reference on how mature operations are documented.

Non-Flight Specific Reported Data

- Administrative/Design
    - Submit date
    - N-number
    - Make
    - Type of aircraft: (airplane, rotorcraft, airship, powered glider)
    - Type of engine: (reciprocating, turbo-propeller, gas turbine)
    - Type of fuel
    - Type of propeller: (fixed pitch or variable pitch/constant speed)
    - Propeller diameter
    - Static RPM at max permissible throttle setting (fixed pitch)
    - Pitch settings (low and high) (constant speed/variable pitch)
    - Geographic location
    - See-and-avoid method
- UAS description
    - Length
    - Height
    - Width (wing span)
    - Maximum allowable gross weight
    - Maximum allowable landing weight
    - Maximum zero fuel weight (turbine powered)
    - Minimum flying weight (turbine powered)
- Weight and balance
    - Most forward Center of Gravity (CG) location
    - Most aft CG location

- Actual aircraft take-off weight (with fuel and payload configuration)
    - Actual CG location for flight (within longitudinal forward and aft limits)
- Manufacturer’s design airspeeds (CAS/IAS in knots or mph)
    - Vs (stall)
    - Vlo (landing gear operating)
    - Vfe (flaps extension)
    - Va (maneuvering)
    - Vc (cruise)
    - Vne (never exceed) [reciprocating]
    - Vmo (maximum operating) [turbine powered]
    - Vd (dive)
- Control station
    - Mission Control Station
    - Launch and Recovery System
    - RCPS
    - Primary operating frequency
    - Secondary operating frequency
    - Other spectrum utilization
- Transponder
    - Transponder model
    - Transponder code
- Launch/recovery method
    - Runway length required
    - Crosswind limitation
- Time in service
- Total airframe time (hours)
- Total engine time (hours)
- Total number of landings (cycles)

Flight Specific Reported Data

- Flight Data
    - Weather
        - Wind speed and direction
        - Visibility
        - Time of day
        - Ceiling
        - Temperature
        - Altimeter setting
        - Density altitude
    - Take-off time
    - Take-off distance
    - Landing time
    - Landing distance
    - Flight time (hours accumulated this flight)

    - Number of landings/cycles
    - Maximum altitude achieved (service ceiling)
    - Maximum distance from GCS
    - Engine
        - Run time
        - Serial number
        - Percent RPM
        - Oil pressure
        - Oil temperature
        - Fuel quantity at take-off
        - Fuel remaining at landing
    - Fuel consumption (gallons per hour or pounds per hour)
    - Payload type
- Crew Data
    - Flight/ground crew (hours and time of day)
    - Pilot-In-Command (PIC)
    - Pilot internal
    - Pilot external
    - Payload operator
    - Instructor pilot
    - Transfer(s)
    - No. of observers
    - Chase aircraft
- Malfunctions or Defects, Incidents, and Accidents
    - Unusual equipment malfunctions (hardware/software)
    - Deviations from ATC instructions
    - All periods of loss of communication
    - Deviations from the special provisions of the UAS FTC COA
    - All periods of total loss link; including duration
    - Incidents/accidents involving the UAS as defined in 49 CFR 830
    - Other
- Data to be Collected on Potential Anomaly(ies)
    - Loss of propulsion
        - Engine failure
        - Fuel starvation
        - Stuck throttle
        - Icing/weather
    - Loss of lift
        - Structural failure
        - Icing/weather
    - Loss of heading/altitude/position information
        - Heading/attitude system failure
        - Navigation system failure
    - Unplanned loss of link
        - Radio frequency interference

        - Flight beyond horizon
        - Antenna masking
        - Loss of GCS
        - Software interrupt between GCS and UAS
        - Atmospheric attenuation
        - Inadvertent deactivation of autopilot
        - Loss of satellite link
    - Loss of control surface performance
        - Stuck servo
        - Autopilot failure
        - Icing/damage to control surface
    - Loss of UAS electrical power
        - Generator failure
        - Backup battery failure
        - Excessive load from payload
    - Loss of GCS
        - Loss of GCS power
        - GCS computer failure
        - GCS transmitter/receiver/antenna failure
    - Mission planning/operator error
        - Flight below minimum en-route altitude
        - Undetected man-made obstacles (towers, cables, etc.)
    - Altitude error
        - Incorrect barometer setting
        - Inadequate alert for altitude deviation
    - Navigation error
        - Navigation system failure
        - Navigation system discrepancy (INS vs. GPS)
        - Map display inaccuracy
    - Failure to see and avoid terrain
        - No capability
        - Autonomous operation
    - Loss of link "fly home" mode – Mission planning error for loss of link mode
    - Unable to see and avoid – Limited capability, Autonomous operation
    - Mission planning error – Inadvertent flight into routes of other aircraft
    - Not seen by other aircraft
        - Strobe/position lights inadequate or failed
        - TCAS failure
        - ATC/UAS operator communication link failure
    - Pilot induced oscillation – System latency
    - Automatic landing system failure – RFI, Handoff errors, Missed approach procedures
    - Operator error
        - Outside weather/wind limits
        - Internal pilot/external pilot handoff errors

- Inadequate operator response
  - Failure to recognize flight critical situation
  - Erroneous flight critical information
  - Delays in information flow
- Incorrect inputs of flight critical parameters – Operator entry errors
- Operator information overload – Tasking or Sensory overload
- Critical information unavailable, inadequate, blocked, etc. – Design dependent
- Latency of flight control commands
  - Operator removed from control loop
  - Non-deterministic software
  - Control link through satellite
- Operator fatigue
  - Inadequate crew rest
  - Task saturation
  - Long/boring mission
- Software paths to unsafe state
  - Unexpected reboot
  - Inadequate software safety process
- Other observational data will be noted for each flight. This data may include subjective evaluation or overview of the flight conducted, and is intended to provide a reporting mechanism for data points not specifically outlined above.

Additional data that is collected and kept include recordkeeping for each UAS in the form of a logbook, a discrepancy log, and the UAS operator will maintain records that allow tracing of each item used in UAS maintenance to the manufacturer of that item, as well as a lot or batch identification of that item. Pre-flight inspection logs including any additional manufacturer-recommended pre-flight actions for other systems also will be performed in accordance with those specified. Discrepancies that result in cancellation of a flight for safety reasons, or that, if not corrected, could have an impact on the safety of a flight, are entered in the discrepancy log. The post-flight inspection, which is also documented, will be a thorough examination of all UAS systems to determine that the UAS has not experienced any unusual wear or damage in the flight just completed, and that the performance of all UAS systems remains within the manufacturers or operator's specifications, whichever are more stringent.

6.4.2 Flight Operations Processes

Flight Readiness Review – This review is required before NMSU launch and operations and covers a review of the operations plan, addresses any deficiencies, and walks through/rehearsal before flight. There are no unique items that inform large UAS operations at non-towered airports.

Airspace and Flight Coordination – Safe operations always include coordination with the broader potentially impacted communities. Structured education and information sessions with the local airport and user community is a benefit for safer and better-informed operations. For safe operations, the flight mission team needs to establish a required notification list for contact before all operations. This includes airport, FAA ATC, and any other locally potentially influencing or impacted government agencies, groups, organizations, etc. (for example, at the NMSU UAS FTS, this includes White Sands Missile Range to deconflict with any frequency jamming operations at

WSMR) This distribution should be retrieved from a site survey form for the operation's location. As an example, for the NMSU UAS FTS contact list includes but is not limited to:

a. Airports
b. Air ambulance services
c. Department Of Defense (DOD) elements in the region (Active, Reserve, and Guard)
d. Fixed-base operator(s)
e. Local ARTCC (for NM the Albuquerque ARTCC)
f. US Forest Service dispatch (Silver City, NM)
g. Related businesses that have an interest in UAS operations

It is a best practice to send out pre-flight notifications for all operations that include dates, altitudes, times, locations, flight radio frequencies, etc. This includes both informal airport and community notifications, as well as the formal notification list. This email should be sent at least one day prior to flight operations. Official notifications are via a NOTAM. The flight team lead should contact the automated flight service station to file a NOTAM before flight with specific times, routes, and/or further information.

Especially important for large UAS operations is the requirement to contact local ARTCC prior to launch and at the conclusion of operations. Per past experience and coordination with our local ARTCC, contact before should be no later than one hour before flight time to allow for intra-facility controller briefing and coordination. At that time the UAS operations group should request assignment of a discreet transponder beacon code(s) for the unmanned aircraft and other support aircraft (e.g., chase) as appropriate. The UAS operations group should be prepared with the following information:

a. Type of flight planned
b. Aircraft identification or pilot-in-command's name
c. Aircraft type
d. Departure point
e. Route of flight
f. Destination
g. Estimated times of departure and arrival
h. Flight altitude(s)
i. Contact name, organization, and phone number
j. Phone number and contact name of the UAS operator on site that can be reached at any time during operations

Flight Operations and Post-Flight Analysis – Specific operational procedures tailored to the flight location should be generated. These include launch preparations, launch, flight, recovery, and post flight. UAS operation procedures should include but are not limited to the following:

- Planning
- Weather requirements
- Acquisition and rendezvous
- Flight
- Detach and recovery

- Detailed emergency conditions
  - Lost link
  - Fly-away
  - UAS crash
  - Non-critical crewed aviation issues
  - Loss of air-ground communications
  - Loss of visual contact with the UAS by the pilot or Visual Observer (VO)
  - Loss of the ability for the chase aircraft to continue to perform its operation and support

Pre-Mishap Plan – Before any flight operations are started, a detailed Mishap Response Plan and checklist should be generated, and checked. The details to be included are not prescriptive, but as an example, the NMSU UAS FTS checklist includes items related to 1) injuries with appropriate response, contact numbers, documentation, and follow on actions; 2) aircraft mishaps with situation assessment, emergency service contact information, airport announcement and notification information, reporting, and follow on actions; 3) fly-away response with detailed flight information; 4) lost link/return to home response with detailed flight information; 5) detailed reporting formats for the mishap and any injuries; and 6) instructions for security team members to control the mishap area.

Site Survey – In advance of all operations, a site survey should be completed that assess and collects all local emergency response contacts, airfield/local points of contacts, airfield location information, relevant ATC information, frequency information, weather, flight area assessments, security information, etc.

Uncontrolled Airports – As noted, many of the required operational elements for safe operations at non-towered airports are part of the fabric that make up the SPOs. It was identified early in the NMSU UAS FTS's existence that significant operations would take place with large UAS at uncontrolled airports. Knowledge and understanding of the local conditions and organization is required. Structured education and information sessions with the local airport and user community is a benefit for safer and better-informed operations. Specific operational procedures tailored to the flight location should be generated. These include launch preparations, launch, flight, recovery, and post flight.

The goal is to reduce the risk of manned aircraft incidents during the conduct of UAS operations at uncontrolled airports. Considerations need to be made for UAS operations in which both internal and external pilots are required for flight. Detailed procedures and checklists for the following operations on the airport should be generated:

- UAS taxi operations
- Taking the runway
- UAS recovery/runway departure

Equipment and personnel locations should be defined to ensure safe standoff distances to runways, taxiways, and other noted infrastructure. Appropriate height limitations for equipment, antennas, and masts need to be determined so as to not interfere with crewed aviation. The following specific steps are used by the NMSU UAS FTS team to ensure flight safety for all users of the airport and the airspace.

1. Launch Preparations: Following the pre-flight briefing, personnel shall deploy to the following assigned locations and carry out assigned tasks.
    a. The UAS shall be towed or transported safely to the starting location via the appropriate taxiways, ensuring that all appropriate procedures for driving on the airport are followed. Hold short lines, speed limits, and appropriate radio calls shall be observed and carried out.
    b. The UAS shall be positioned to start the engine and to go through the IP and EP checks for the UAS (as appropriate for the system). At no time shall the UAS be left unattended on the taxiway. If a manned aircraft approaches on the taxiway during checks, the UAS shall be moved as necessary to enable the manned aircraft to proceed.
    c. Whenever taxiing, all appropriate aircraft/airport practices and rules shall be followed.
    d. The UAS shall remain at the hold short line until the PIC has announced that the UAS is cleared to proceed onto the runway. This shall occur after the PIC has monitored the common traffic advisory frequency/universal communications (CTAF/Unicom), observed the radar for situational awareness (as appropriate), and checked with the visual ground observers.

    Note – A best practice is to have codified UAS taxi procedures and checklist that addresses equipment needed (radios, lights, support equipment, etc.), rules of operating on the airport surfaces, hold short lines, etc.

2. Launch
    a. If no aircraft are noted in the pattern (for the using runway) or preparing to take off, then the launch sequence shall commence. The PIC shall inform the EP to take his position and the crew chief or comparable position to take the runway. At this time, the EP shall take his position at the edge of the runway, and the EP safety truck shall be put into position while the UAS is positioned for the launch. During this time, the VOs shall remain vigilant for manned aircraft, both in the air or on the ground, visually and through the monitoring of the CTAF. The PIC shall continue to check the radar for aircraft in the vicinity (if radar in use).
    b. If a manned aircraft is going to be utilizing the runway (take-off or landing), the UAS crew immediately shall move off the runway/safety zone unless the pilot of the manned aircraft makes contact on the CTAF and states that they will use a different runway. This relocation shall include the EP, the EP stand, the EP safety truck/vehicle, and the UAS.
    c. If aircraft are taking off or landing on other runways, the PIC shall wait for the manned aircraft to complete its task before proceeding with the launch.
    d. If no manned aircraft are noted, then the launch shall proceed as normal.

    Note – A best practice is to have codified taking the runway procedures and checklist that addresses the personnel, reporting, go-no go, actual flow of the process including checks and radio calls, etc.

3. Flight

a. During flight, the ground VOs shall remain diligent for manned aircraft traffic, reporting as required to the PIC while the UAS is in their range.
b. Once the UAS and chase plane (if planned to be operating beyond line of sight or ground VO protocols) proceed away from the airport, positive control from the ground-based primary observer to the airborne VO shall occur before the PIC allows the ground VOs to cease their duties.
c. When the UAS and chase plane return, the ground VOs shall confirm that they have positive contact on the UAS to the PIC prior to the airborne VO relinquishing responsibility.

4. Recovery
    a. Prior to recovery, the VOs shall ensure that no manned aircraft are noted in the UAS path or pattern. The PIC shall check with the VOs to confirm, (checking the radar is optional) and monitor the CTAF/Unicom for traffic before authorizing the UAS recovery. This shall include checking for manned aircraft inbound, in the pattern, and on the ground.
    b. The PIC shall make the appropriate calls on the CTAF/Unicom prior to and during the recovery process.
    c. While in the process of recovery, if a manned aircraft is noted coming into the pattern, then the UAS shall remain aloft and let the manned aircraft lands.
    d. Once the UAS is safely on the ground, the UAS and entire crew shall vacate the safety zone as soon as possible.
    e. Following the flight, the UAS shall not be left unattended on any taxiway or inside the safety zone.

    Note – A best practice is to have codified UAS recovery/runway departure procedures and checklist that addresses people, responsibilities, setup (ex. if hook lines need to be deployed), equipment needed, shut down/safing of aircraft, step by step to remove the aircraft and equipment form the runway, etc.

5. Post Flight
    a. The systems shall be shut down according to manufacturer's procedures and checklist.
    b. Following the flight, the appropriate data shall be collected in accordance with SOP 2.9.
    c. The entire crew shall be debriefed and reports and data collected shall be archived.

UAS Chase Aircraft Operations – Chase aircraft operations if required should include 1) operational procedures; 2) aircraft compatibility checks to ensure altitudes, speeds, and performance can be matched for safety; 3) chase aircrew requirements; and 4) other related procedures focusing on planning, weather, UAS acquisition and rendezvous, flight, detach and recovery, and detailed emergency conditions. Emergency conditions include but are not limited to the following:

- Lost link
- Fly-away

- UAS crash
- Non-critical crewed aviation issues
- Loss of ai-r-ground communications
- Loss of visual contact with the UAS by the pilot or VO
- Loss of the ability for the chase aircraft to continue to perform its operation and support

UAS Contingencies – The UAS contingencies are similar to the chase plane contingencies listed above.

Spectrum – Adhering to the required frequency spectrum usage for the UAS and operations is in some ways straight forward and others may be unique to the flight location. With all UAS flights and operations, there are requirements to be met with the use of spectrum that are not just germane to UAS operations on and around airports. These are not repeated here. Because of our launch and flight locations, the NMSU UAS FTS has to also coordinate with the DOD Area Frequency Coordinator because of the operations and potential impacts of operations at WSMR. There are also frequency considerations with other DOD entities like Holloman Air Force Base.

The NMSU UAS FTS spectrum coordination has three parts – analysis, operational planning, and flight operations. The team performs a number of steps during analysis, operational planning, and as part of each flight activity. As an example, the key steps related to assessing these operations when working with WSMR include the following:

1. The proponent provides frequency information.
    a. If the proponent currently is using FCC-licensed frequencies, a copy of the license is provided.
    b. If the proponent uses DOD frequencies, documentation of the DOD authorization will be provided for coordination with the DOD Area Frequency Coordinator.
    c. If ISM/non-licensed band frequencies are used, all pertinent information on the communications system will be gathered and analyzed to ensure compliance.
2. The communication/frequency analysis is an important part of the hazard/risk mitigation process.
3. The risk mitigations and limitations for communications are an important part of the analysis process and are placed into the operations plan for guidance.
4. Perform frequency/power verification ground checks on all UAS systems and frequencies at the time of inspection.
5. The Mission Commander (MC) contacts the DOD Area Frequency Coordinator a minimum of three days before scheduled flight activity.
6. The DOD Area Frequency Coordinator compares the UAS communications system information using the Integrated Frequency Deconfliction System and provides the information and results to WSMR Range Control.
7. Range Control uses the information and results to perform future and real-time frequency deconfliction against their WSMR range schedule and operations.
8. Prior to flight, the MC checks UAS frequencies with a spectrum analyzer prior to transmitters being energized to ensure the frequencies are clear for flight and recorded on the Flight Data Form.

9. The UAS pilots/operators, as part of their flight duties, will monitor the link (up and down links) to ensure that UAS communications remain at the appropriate levels.
10. If a conflict is noted, Range Control will advise UAS FTS of the conflict and resolution will occur before flight testing or operations.
11. If communication issues are noted during flight, the MC will advise the PIC to return to base as soon as safely possible.

It should be noted that after each mission there is a debrief in which any issues or lessons learned are captured. These are then incorporated into the support documentation for the program, SOPs, and for operations. It is also worth highlighting that the operations of large UAS from a non-towered airport are well integrated with ABQ center, KLRU management, and the local aviation community.

6.5 Recent NM Flight Operations Example

The NMSU UAS flight team recently performed a series of large UAS flights from the Las Cruces International Airport (KLRU) to help Embry Riddle Aeronautical University and the FAA assess how large UAS can be safely integrated with current crewed aviation already under ATC control. The flights involved flying multiple scenarios with the Aerostar UAS under the normal UAS operational procedures while at the same time, the UAS was integrated into simulated flight environments. Operation in the actual flight environment followed the elements as laid out previously. There were two simulated controlled environments as follows:

- Air Traffic Control Environment
    - All aircraft including UAS receive air traffic services from Demo ATC as applicable.
    - Pilots (including RPICs) communicate with ATC as required.
- Corridor Control Environment (CCE)
    - UASs cooperatively separate from one another within corridors in accordance with Urban Air Mobility concepts.
    - RPICs/operators utilize services as applicable via the Federated Network.
    - Aircraft enter and exit the CCE at Corridor Entry/Exit Points.

The simulated environments included a Demo ATC, a Federated Network, and Provider Services for urban air mobility who all interfaced with the UAS Remote Pilot in Command. There were a number of interesting conclusions from these live flight exercises and testing which had particular foci on operation in mountainous areas, Class B operations, and transitional operations between ATC Environment and CCE. The specific conclusions and lessons learned from this other testing is not germane to this report, but some of the generic operational considerations and lessons learned are. Three items stood out as either additional lessons learned or highlighted what is already in the knowledge base. These include the following:

1. Long distance and duration flights must consider the local weather, transition weather, and downrange weather to assess flight performance. In this particular case, launch and the bulk of the flight operations weather was nominal. Winds in New Mexico at certain times of the year can be a factor. Downrange, flying in mountainous terrain, the UAS encountered expected but challenging issues with mountain waves, high wind, and extreme cold conditions. Altitude adjustments were made to counter these conditions.

2. A persistent geographic challenge in NM is deconfliction with potential jamming by the Federal Government/Military. During these missions, flight operations were suspended two of the seven days due to lost C2 link caused by testing at White Sands Missile Range and NASA.
3. Any mechanical/operational issues need to be addressed as quickly as possible to avoid impact to ongoing crewed airport operations. This is part of the planning and execution of the operations to ensure that UAS aircraft and personnel are only on active taxi-ways and runways for the least amount of time as practical.

These operations highlight that no matter how mature the planning, SOP's, or the experience of the flight crews, there are always lessons to be learned and added to the knowledge base.

7 UAS AIR RISK: ON AND AROUND AIRPORTS

The use of UAS has risen due to their small size, cost-effectiveness, and versatility in various applications. For non-military purposes, these drones are typically allowed to operate below 400 feet. This provision helps segregate drone operations from those of crewed aircraft, thereby minimizing conflicts in the NAS. However, this does not eliminate the challenges and additional risks associated with low altitude flights, particularly on and around airports, where UAS are used for commercial and security purposes.

Operation of UAS in controlled airspace like airports demands permission from authorities such as ATC and other governing agencies. The integration of UAS operations into these spaces necessitates a comprehensive understanding and estimation of associated risks. The potential of malfunctions, leading to uncontrolled drones, introduces multiple risks within a bustling airport environment. These risks include damage to infrastructure, disruption of ground operations, and airborne collisions. If left unaddressed, these risks could disrupt regular operations, inflict economic damage, and in the worst cases, result in loss of human lives. The risk analysis conducted through ADS-B analysis and various simulations helped to create a rudimentary risk assessment tool to help visualize various risks associated with crewed aircraft within an airport environment.

The research specifically analyzed risks associated with UAS and crewed aircraft flying below 1000 feet and within a 5-mile radius of an airport. The high volume of airport operations and low-altitude flights increase the collision risk within this environment. The analysis used a probabilistic approach using historical ADS-B data to model the aircraft's trajectory in three-dimensional space and simulate various fail-safe scenarios for UAS. To further visualize risk, the risk assessment tool could be expanded to include specific waypoints or routes to assess risk. The effort aimed to calculate the probabilities of Mid-Air Collisions (MAC), Near Mid-Air Collisions (NMAC), and Well Clear (WC) violations between uncrewed and crewed aircraft. The Grand Forks International Airport, known for its high volume of operations, serves as the model for initial studies. Historical ADS-B data is scrutinized statistically to identify peak traffic times and extract flight trajectories for analysis. UAS-flight risk assessments consider various factors such as aircraft speed, traffic volume, and probability distributions of UAS trajectories.

The SIMLAT simulation results illustrated that upon a failure of the UAS's GPS, the UAS persisted in its original flight direction. Conversely, in other failure scenarios, the UAS returned to its home location. However, minor variations were observed in the exact heading of the UAS, diverging slightly from the straight line between two waypoints. Furthermore, the UAS couldn't navigate at a right angle at the building corners, which made it impossible to predict the precise UAS trajectory post-failure. This situation naturally suggested the application of a probabilistic approach to estimate the likelihood of various UAS failure scenarios.

For analysis, simulations focused on instances where the UAS's direction was entirely random. In contrast to this approach, this study generated random normal distributions directly, using mean values defined by the initial velocity and standard deviation. Aircraft traffic is extracted from the ADS-B data. ADS-B data during the months from April to September 2021 is obtained from the ADS-B receiver deployed at the Grand Forks international airport by Flighradar24. From the ADS-B data set, researchers extracted flight-specific information like time, location (latitude and longitude), and altitude. As previously mentioned, the altitude AGL is calculated using the ADS-B altitude data in conjunction with digital elevation maps obtained from USGS.

The analysis primarily focused on identifying and characterizing the temporal patterns in the air traffic flow. In this regard, the hourly, weekly, and monthly flight traffic data are analyzed. The outcome of the analysis is shown in Figure 13 and Figure 14. The following section presents different scenarios considered for data analysis.

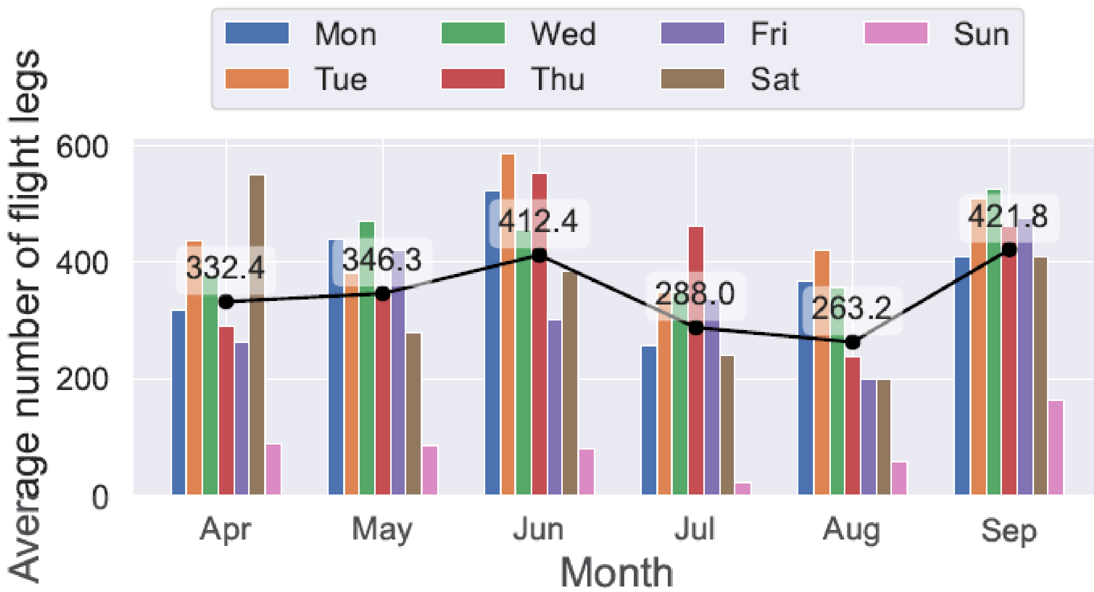

Figure 13. Monthly statistical histograms corresponding to the Grand Forks.

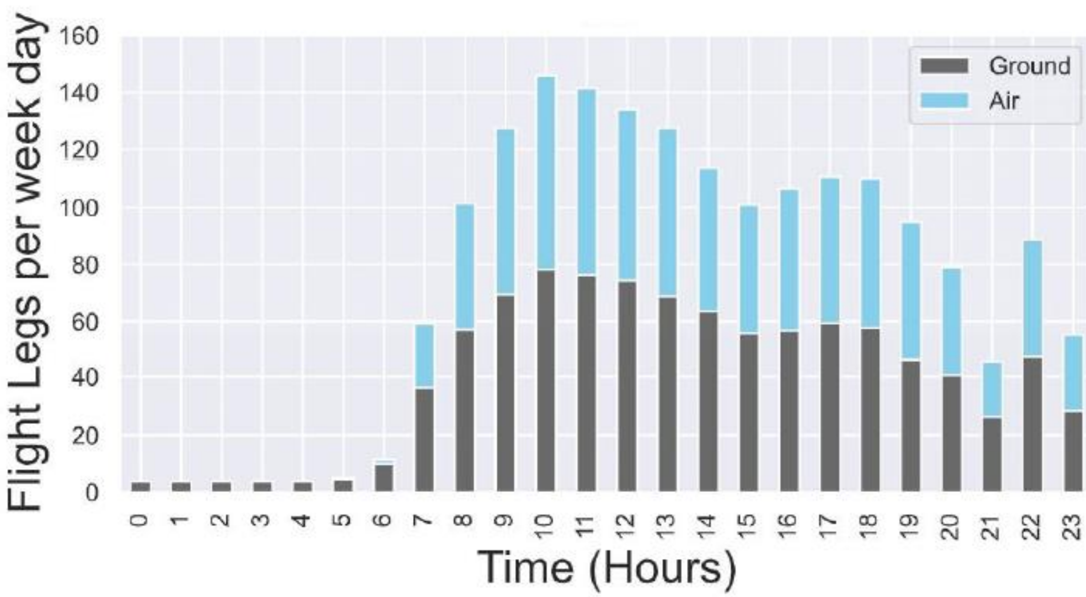

Figure 14. Hourly statistical histograms corresponding to Tuesdays at the Grand Forks.

Probability Risk Assessment (PRA) with respect to a single crewed aircraft with a UAS was also investigated. The aircraft's flight path is derived from the ADS-B location series as a function of time. The real ADS-B traffic data with the simulation-generated UA trajectories. In the simulation, UAS before failure is assumed to have operated from a nearby building within the airport. This is done with the assumption that the UAS is used for applications such as building inspection.

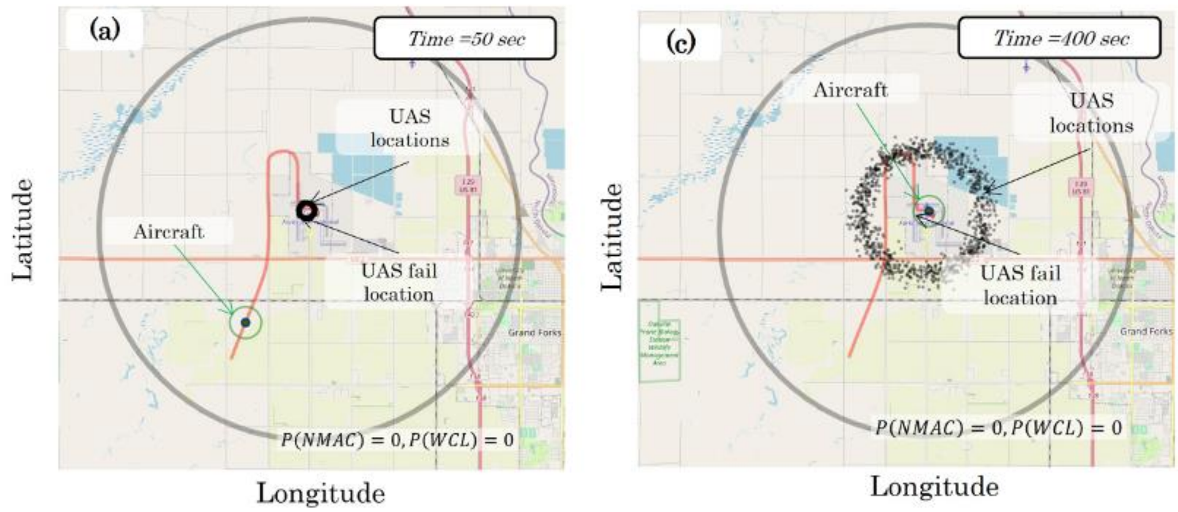

Figure 15. UAS probable locations and aircraft locations at times (a) 50 sec and (c) 400 sec.

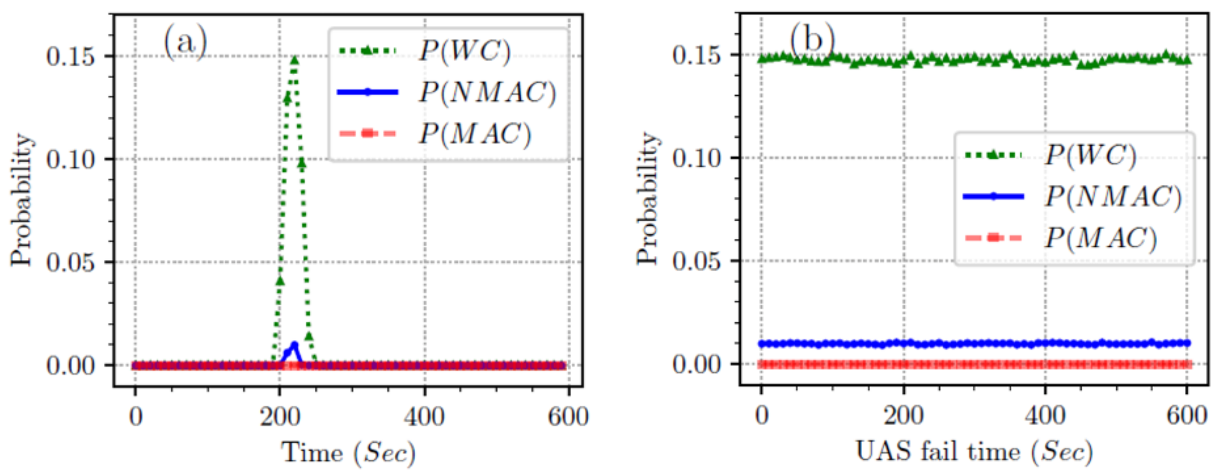

Figure 16. Probabilities of MAC, NMAC, and WC at when the (a) UA failure occurred at ’0’ seconds (b) Peak probabilities when UAS failure occurred at different times.

The operation of UAS is simulated with the real ADS-B traffic to calculate the PRA via an in-house simulation platform developed using in-house simulator. The simulation platform overlaps probabilities associated with the three risk volumes of the landing path of a single aircraft were then determined. The trajectory of both aircraft are shown in Figure 15. The results are presented in Figure 16. Figure 16(a) indicates that the P(MAC) is almost zero, while P(NMAC) reaches its peak value of 0.0099, and the value of P(WC) reaches its maximum value of 0.147 when the time = 220s. The probability value is time dependent meaning it depends on the time UAS failure occur and when the crewed aircraft in near. The main factors include the crewed traffic in the airport, the traffic pattern of the crewed aircraft, and operation location of the UAS before the failure occurs. To investigate the effect of the failure time, further simulations were conducted while keeping all the remaining parameters constant and varying the UAS fail time. The location of the aircraft and the UAS positions are shown in Figure 15. The result presented in Figure 16(b) shows the probability value in the simulation with respect to UAS fail time.

Simulations are done to calculate the PRA during the peak traffic. The flight traffic data from the peak time period is considered for this scenario.

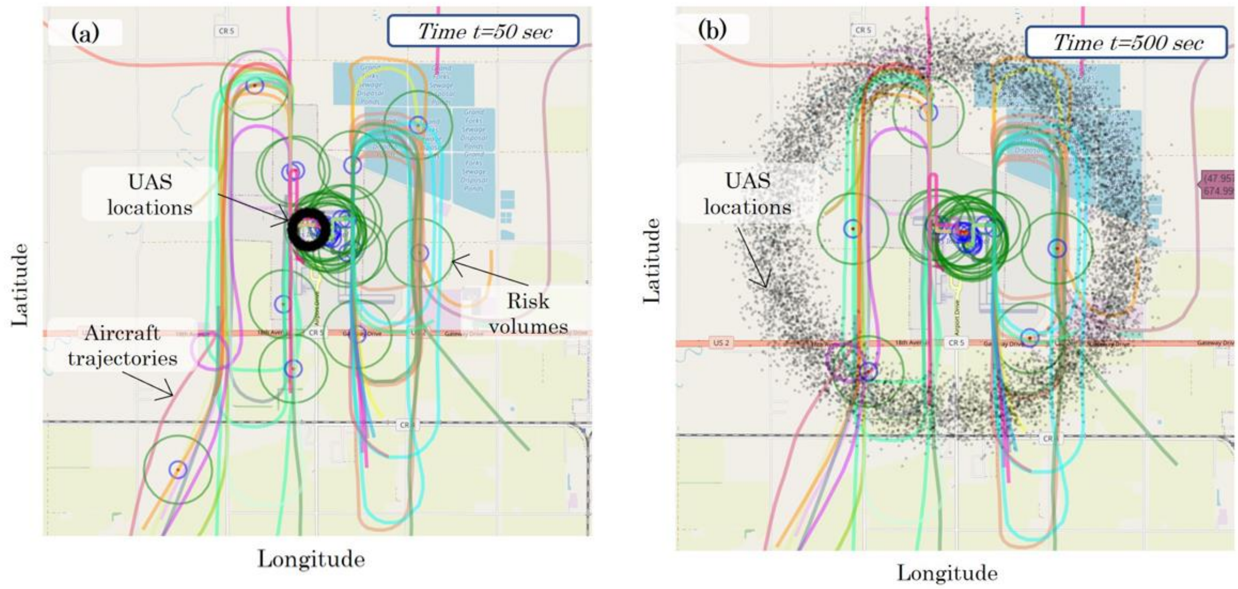

Figure 18. Probabilities of MAC, NMAC, and WC at when the (a) UA failure occurred at ’0’ seconds (b) Peak probabilities when UA failure occurred at different times.

The probabilities associated with the three risk volumes are calculated when the air traffic is at its peak. This analysis shows that the P(MAC) value is negligible, the value of P(NMAC) reaches its maximum value of 0.31, while the value of P(WC) is in its maximum value of 1.0. Similar to the previous case, the risk probability is time-dependent, and the highest risk occurs within the first 200 seconds (about 3 and a half minutes) after the UAS failure. The reason for high P(WC) is that the UAS failure location is relatively close to the air traffic as shown in Figure 18.

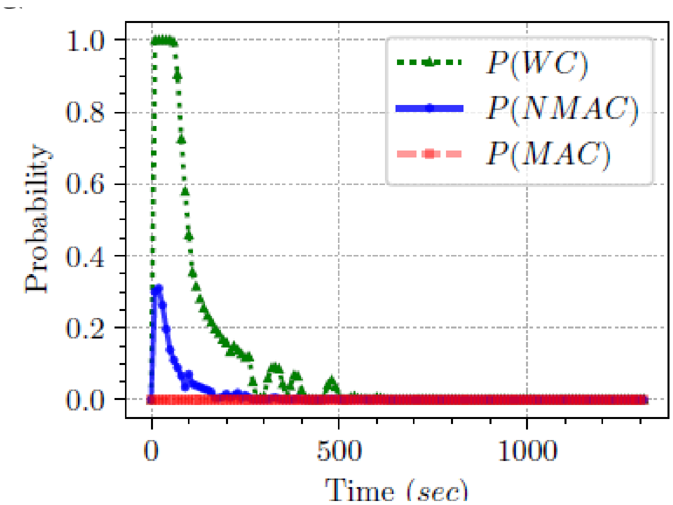

Figure 19. Probabilities of MAC, NMAC, and WC during the peak traffic.

The probabilities associated with the three risk volumes are calculated when the air traffic is at its peak. The UAS failure time is assumed to be 10:00:00 (CT) and the results are shown in Figure 19.

Probability Risk Assessment of a UAS failure within the airport traffic is done by considering multiple failure locations. To achieve this goal, a structured approach was adopted by considering an area of 3 miles × 3 miles around Grand Forks airport. A uniform grid of 20×20ft was generated that gives uniform squares with dimensions approximately near to 0.15 mi each side. Each intersection point of the grid is taken as a failure location of UAS. The location of UAS failures plays a crucial role in determining the risk probability. The contour map of the P(WC) is shown in Figure 20. The map illustrates that the maximum P(WC) value is near the airport center, with the highest value of 1.0. The P(WC) value gradually decreases as the failure points are away from the airport center. The P(WC) value declines and becomes less than 0.0001 after approximately three miles. The near-miss collision P(NMAC) is similarly highest at the center of the airport, with a value of 0.54, and has reduced while considering the UA failure locations away from the airport. Interestingly, there is a location A marked in Figure 20-(b) which is far from the airport center and runways show a higher risk probability than the surrounding areas. This is the point where more incoming air traffic is descending to land towards the runway. These results highlight the importance of this research, as it is not always apparent to identify such high-risk areas far from the airport center. Nevertheless, the analysis provided here can reveal such hidden high-risk locations, which can be utilized to optimize UAS operations within airports.

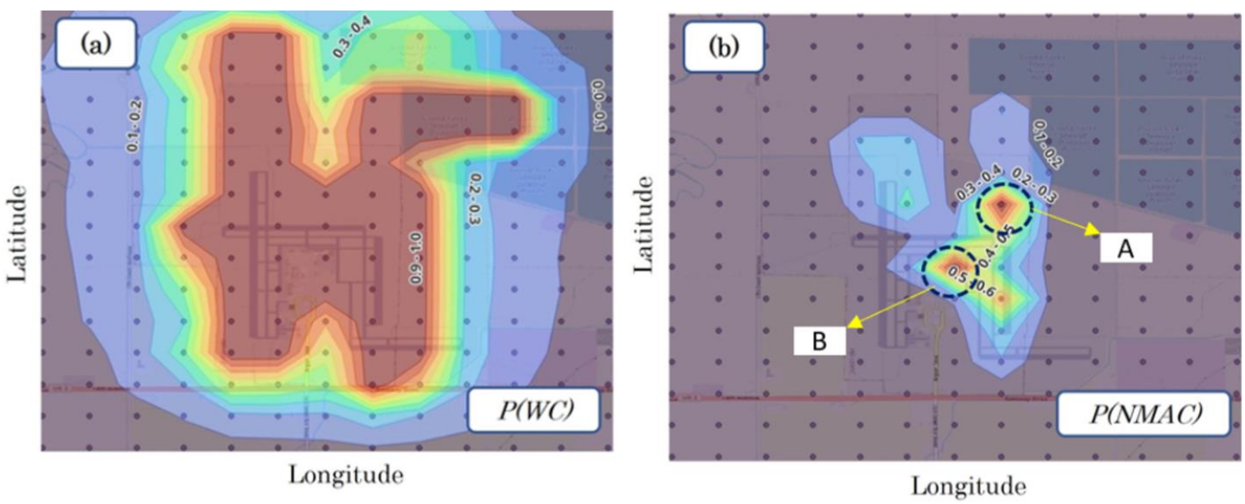

Figure 20. Risk probability dependence on the UAS failure location simulated in scenario-III (a) risk probability associated with well-clearance (b) risk probability associated with NMAC.

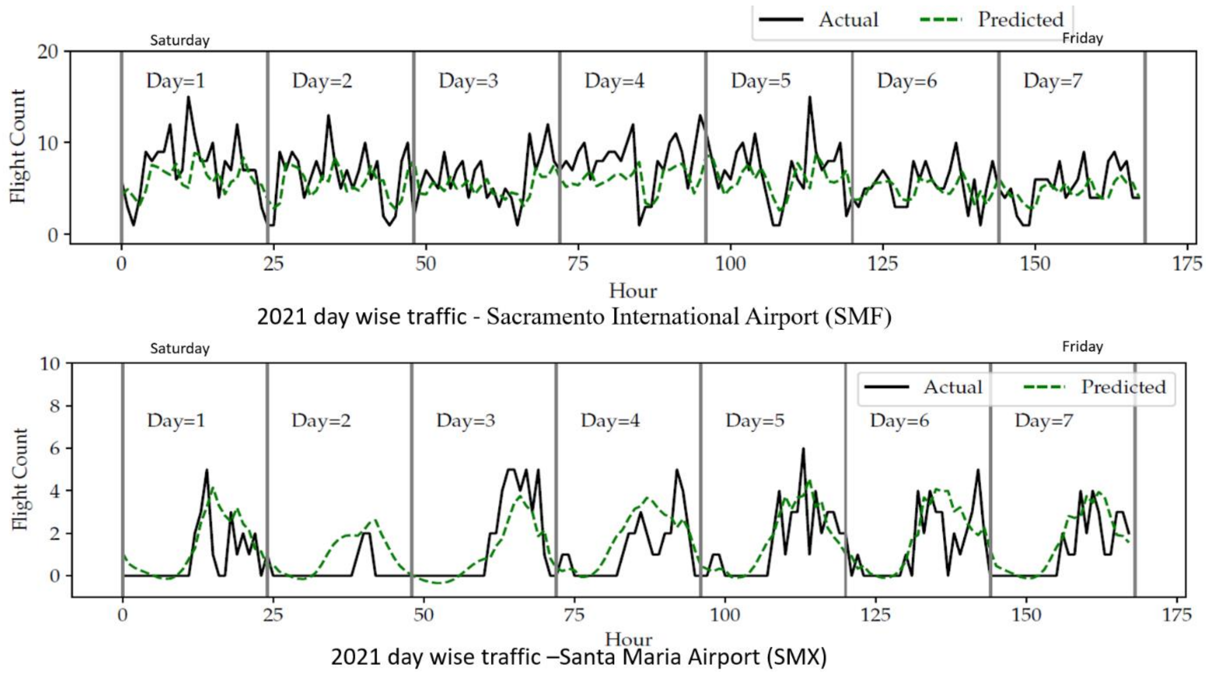

Figure 21. Difference in traffic pattern of SMF and SMX airport.

The findings of this analysis reveal that the mean and standard deviations associated with the heading direction and velocity variables have a substantial influence on the estimated probabilities. Additional analyses were conducted, taking into account various airspace classifications. Due to limitations of flightradar24, more reliable open-sky database with information available in California was used to gather ADS-B data. We examined data from Class D airports, specifically Santamaria (SMX), and compared it with the traffic from Class C airports, using Sacramento International Airport (SMF) as a case study. The breakdown of daily traffic patterns is represented in Figure 21. The data used for these analyses is from the year 2021. It's apparent from this study that there's considerable nighttime activity at the Class C airport (SMF), while the Class D airport (SMX) observes relatively minimal traffic during nighttime hours. It is also interesting to note that the average weekdays traffic are high compared to weekend traffic in a class D airport and vice versa in a class C airport. The results indicate the comparison between SNF and SMX airport will not be same for a different airport. For picking the best time to operate UAS out prediction shows the different time of the day where an operator can choose to fly. The team used a Machine Learning based approach to determine the best time to operate a flight. In this approach, using Recurrent Neural Networks, specifically Long Short-Term Memory models, to predict airport flight counts for the subsequent week, learning from historical data to recognize weekly and daily traffic patterns. The training data comprises two primary variables: "hours" and "flight count," amounting to a dataset of 8760 data points, each representing flight count for a specific hour across 365 days. The long short-term memory model, trained with fixed-length input sequences (168 hours), learns from these patterns to make forecasts (marked in green dotted line). Performance evaluation of the model, based on metrics such as R-squared, mean squared error, root mean squared error, and mean absolute error , indicates promising preliminary results, with root mean squared error values between two and three, suggesting a high degree of accuracy. For this analysis, the team used data from OpenSky networks. Figure 22 shows the traffic pattern for the year 2021(365 days). The anomaly in the beginning of Class-D is due to the missing data in the month of January 2021.

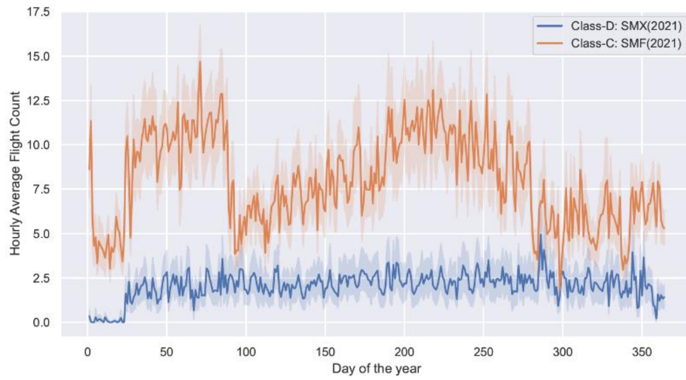

Figure 22. Flight traffic (flight count) Vs days of a year(2021) from SMX and SMF airports.

8 LESSONS LEARNED

The flight testing addressed the similarities and differences between use case hazards and mitigations based on airspace class and towered/non-towered airport operations and the uniqueness of each airport, the communications between UAS operators, ATC, and other airport users/managers during UAS operations on and around the airport surfaces, the ability of the SMS process to identify and mitigate hazards prior to conducting the flight operations, and the effectiveness of the policies and procedures developed by the research team for operating on and around airport surfaces. The following are some of the lessons learned during the research.

8.1 Lessons Learned from the SRA/SMRP Processes

There were a number of specific lessons learned from the SRA/SRMP process that was used. It should be noted that the process used was the one employed by the FAA UAS Test Sites that is approved by the FAA for the FAA UAS Test Sites and is consistent with the FAA official process, but not the same "official" process that an external FAA customer may use.

- The Safety Risk Analyses developed for all three use cases were very similar in the hazards identified and potential mitigation strategies proposed for on-airport operations.
- The Safety Risk Analyses procedures utilized by the research team were sufficient to obtain the required flight permissions from the FAA for all of the use cases.
- The research team's pre-Safety Risk Management Panel analysis of the materials submitted for the large drone COA identified some areas for language improvement, but otherwise concluded that the materials submitted were sufficient to evaluate the risk of the operation.

8.2 Lessons Learned from the Emergency Response Use Case

8.2.1 Lessons Learned from the Planning Phase

The main concern from the FAA airspace authorization processer was that for a UAS operation to occur over a movement area, it had to be closed with a NOTAM. Deploying from ARFF to a scene would therefore require a NOTAM. Alert 3's or 4's would close the airport until the determination could be made of what could be opened. AJT reviews all on-airport requests, so hopefully, they would consider an Alert 3/4 in lieu of the NOTAM closure, allowing the UAS to deploy from ARFF.

For this Operation, what could be beneficial is an authorization that has a special provision with wording such as “Operations allowed only during an Alert 3/4 call, unless a NOTAM is filed at least 24 hours in advance…”. This would not only allow researchers to conduct the demonstration for the project with a NOTAM posted, but also serve as a template for future airports hoping to conduct real-world operations in the future during an emergency call and for emergency training purposes.

8.2.2 Lessons Learned from the Demonstration

Once the demonstration concluded, KSU met with the members of the Salina Airport and ARFF, that participated in a debrief of the day’s events; from the ARFF perspective, the communication from the RPIC that was given to ARFF #1 and #4 by the ARFF personnel located with the RPIC could be improved. If a demonstration of this type were to occur again, the communication procedures would need to be discussed beforehand to ensure the relevant information was given in a clear and concise manner with predetermined language and sequencing.

The ability to send the UAS video feed into the ARFF truck would be an added benefit. At times, the driver is the only crew member on the scene until other units arrive. This individual has several priorities ahead of communicating with a UAS operator. Sending the live feed to the interior of the truck would increase the driver’s situational awareness.

8.3 Lessons Learned from the Building Inspection Use Case

Electromagnetic interference at the designed take-off location due to concrete/re-bar or other underground electrical/spectrum interference can interfere with an aircraft's ability to takeoff. To mitigate this for future UAS operations, airport design may need to take into account power distribution and other sources of magnetic interference when dictating where UAS are allowed to fly or take off and land from.

The GPS coverage in an area can be less than anticipated, causing significant error in actual altitude above ground. More research is needed to analyze GPS accuracy to mitigate UAS operations on and around airports, especially since GPS accuracies tend to be less near buildings and at lower altitudes. Choosing an emergency landing area during preflight preparation must consider the GPS coverage and accuracy. Lack of preplanning could result in compounding emergencies resulting in greater risk.

UAS operations on airport need to be coordinated. During these operation, two other UAS operations were also approved in the airport landside area and ATC did not seem to have real-time location data on any of the other operators. The integration of flight data into ATC systems could help ATC personnel obtain greater situational awareness to manage complex traffic operations between UAS and crewed aircraft.

8.4 Lessons Learned from Large UAS Use Case

- The conditions at the airport will dictate what equipment is required on a UAS operating at the airport during specified weather conditions.
- Designing aircraft and operations to deal with these challenges will be essential for safe operations on airport surfaces in snowy regions.
    - Small tires may not provide enough traction for high-speed taxiing.
    - Differential braking is needed to control sliding.

    - Converted traditional cargo aircraft will have some of these issues handled (tire size, for example), but how the remote pilot or autonomy handles braking (brakes full on vs. differential braking) could create a challenge.
- The process for getting all of the approvals required to operate a large drone at an airport is not clear.
    - You can get different responses from different FAA Lines of Business on what is required.
    - Who has authority vs who can only make recommendations?
    - You can get airspace approvals for the airport without being approved to operate at the airport.
    - Ground NOTAMs must be issued in addition to airspace NOTAMs for placing a GCS at different locations at an airport. The GCS became construction equipment and required associated paperwork to be adjacent to a taxiway.
- An airport's not clearing of the trees in the Runway Safety Area or ROFA can inhibit drone operations at an airport.
- An airport manager giving permission for a ground control station trailer to be located adjacent to a runway is not sufficient to meet FAA recommendations /regulations for that placement.

8.5 Lessons Learned from NMSU Experience

The NMSU UAS Flight Test Site, has gathered a large number of lessons learned through these large UAS operations. While previous sections present a number of detailed steps, these are all focused on flight and operational safety. From decades of experience, it has been found that a detailed and methodical analysis and assessment before any operation take place at airports is required for safe operations. This "paper trail" is also needed to document that all elements were assessed and the operation deemed safe to proceed. Notifications of all potential stakeholders is also required for safe operations. Detailed planning in advance, and practice of these plans and procedures in advance increase safety. A listing of key lessons learned based on hundreds of operations completed by the NMSU UAS Flight Test Site team at non-towered airports is presented below.

- Large UAS need a full up safety assessment before being allowed to operate in the same spaces as crewed aviation.
- Flight and support personnel need to have the required training as detailed by the local airport and must follow all on-airfield rules.
- Extensive planning for anomalies and emergencies needs to be completed and reviewed before flight and with airport management.
- Engagement with local airport management and its user community is required to properly integrate into the normal airfield operational flow.
- After an aircraft has been approved for operations at a non-towered airport, any changes to aircraft need to be reviewed to ensure that modifications or alterations will not impact the previously reviewed safety considerations.
- In advance of all operations, a site survey should be completed that assess and collects all local emergency response contacts, airfield/local points of contacts, airfield location

information, relevant ATC information, frequency information, weather, flight area assessments, security information, etc.

- Structured education and information sessions with the local airport and user community is a benefit for safer and better-informed operations.
- Establish a required notification list for contact before all operations. This includes airport, FAA ATC, and any other locally potentially influencing or impacted government agencies, groups, organizations, etc. (for example, the NMSU UAS FTS, this includes White Sands Missile Range to deconflict with any frequency jamming operations at WSMR) This distribution should be retrieved from a site survey form for the operation's location. As an example, for the NMSU UAS FTS contact list includes but is not limited to:
    - Airports
    - Air ambulance services
    - DoD elements in the region (Active, Reserve, and Guard)
    - Fixed-base operator(s)
    - Local Air Route Traffic Control Centers (ARTCC) (for NM the Albuquerque ARTCC)
    - U.S. Forest Service dispatch (Silver City, NM)
    - Related businesses that have an interest in UAS operations
- Pre-flight notifications for all operations are required that include dates, altitudes, times, locations, flight radio frequencies, etc. This includes both informal airport and community notifications, as well as the formal notification list. This email should be sent at least one day prior to flight operations.
- Contact automated flight service station to file a NOTAM before flight with specific times, routes, and/or further information.
- Contact local ARTCC prior to launch and at the conclusion of operations. Contact before should be no later than one hour before flight time to allow for intra-facility controller briefing and coordination. At that time the UAS operations group should request assignment of a discreet transponder beacon code(s) for the unmanned aircraft and other support aircraft (e.g., chase) as appropriate. The UAS operations group should be prepared with the following information:
    - Type of flight planned
    - Aircraft identification or pilot-in-command's name
    - Aircraft type
    - Departure point
    - Route of flight
    - Destination
    - Estimated times of departure and arrival
    - Flight altitude(s)
    - Contact name, organization, and phone number
    - Phone number and contact name of the UAS operator on site that can be reached at any time during operations
- Before any flight operations are started, a detailed Mishap Response Plan and checklist should be generated and checked.

- Specific operational procedures tailored to the flight location should be generated. These include launch preparations, launch, flight, recovery, and post flight.
- Detailed procedures and checklists for the following operations on the airport should be generated:
    - UAS taxi operations
    - Taking the runway
    - UAS recovery/runway departure
- Chase aircraft operations if required should include the following:
    - Operational procedures
    - Aircraft compatibility checks to ensure altitudes, speeds, and performance can be matched for safety
    - Chase aircrew requirements
    - Procedures
        - Planning
        - Weather requirements
        - Acquisition and rendezvous
        - Flight
        - Detach and recovery
        - Detailed emergency conditions
            - Lost link
            - Fly-away
            - UAS crash
            - Non-critical crewed aviation issues
            - Loss of ai-r-ground communications
            - Loss of visual contact with the UAS by the pilot or VO
            - Loss of the ability for the chase aircraft to continue to perform its operation and support
- UAS operation procedures should include the following:
    - Planning
    - Weather requirements
    - Acquisition and rendezvous
    - Flight
    - Detach and recovery
    - Detailed emergency conditions
        - Lost link
        - Fly-away
        - UAS crash
        - Non-critical crewed aviation issues
        - Loss of air-ground communications
        - Loss of visual contact with the UAS by the pilot or VO
        - Loss of the ability for the chase aircraft to continue to perform its operation and support

- Frequency allocation/authorizations need to be obtained in advance and all systems checked before flight to ensure no external interference from DOD, agency, or other sources.
- Long distance and duration flights must consider the local weather, transition weather, and downrange weather to assess flight performance.
- Before flight, deconfliction with potential jamming by the Federal Government/Military needs to be considered to ensure no lost C2 link caused by external testing.
- Mechanical/operational issues need to be addressed as quickly as possible to avoid impact to ongoing crewed airport operations. This is part of the planning and execution of the operations to ensure that UAS aircraft and personnel are only on active taxi-ways and runways for the least amount of time as practical.

9 RECOMMENDATIONS FOR FUTURE UAS OPERATIONS, POLICY, AND REGULATION

- Development of better guidance for operators requesting UAS waivers. The team recommends a series of questions be developed that ATC, Airport Managers, and UAS operators would mitigate risk together.
- Using SRA documentation, develop a standard list of potential risks associated with flights on and around airports that include risks that must be addressed at a minimum for a waiver to be approved.
- To assist users who have less aviation related experience, it would be valuable to create a Flight Risk Assessment Tool for UAS users to help identify 'variable' risks before a flight – variable risk that were determined critical include weather, airspace density, UAS saturation levels for a given area at the airport, GPS reliability, traffic 'patterns based on ADS-B or similar technology, and critical infrastructure located at each airport.
- PRAs should be conducted to better identify risk likelihood and saturation levels for UAS operating on and around airports with crewed aircraft.
- Development of expectations for pilots to understand aircraft programmed/automatic response to a given failure and understand time needed react to a given emergency should the automation fail.
- If systems are fully autonomous, reliability of UAS systems must be proven and in the event of an abnormal or emergency scenario, the UAS must react consistently to manufactures documentation.
- Access to real-time data of UAS movement on and around airports can improve safe operations. This could include integration of information submitted to LAANC with ATC. ATC requires the entire air picture, and this could be enhanced by the inclusion of all planned and in process UAS operations. As previously noted, for the testing conducted as part of this research, the three UAS operations were approved at the KGFK airport. There was no known synchronization of the various UAS flights to ensure oversaturation and no method for UAS operators to identify the other UAS operators and under what rules they were operating.
- Airport construction must be considered in relation to design impact on UAS operations.
- During KSU's approval process, the main concern from the FAA airspace authorization processer was that for a UAS operation to occur over a movement area, it had to be closed

with a NOTAM. Deploying from ARFF to a scene would therefore require a NOTAM. Alert 3's or 4's would close the airport until a determination could be made of what could be opened. 'AJT' reviews all on-airport requests, so hopefully, they would consider an Alert 3/4 in lieu of the NOTAM closure, allowing the UAS to deploy from ARFF.

- During KSU's operation it would be beneficial for an authorization that has a special provision with wording such as "Operations allowed only during an Alert 3/4 call unless a NOTAM is filed at least 24 hours in advance…". This would allow operators to conduct a similar project with a NOTAM posted but also serve as a template for future airports hoping to conduct real-world operations in the future during an emergency call and for emergency training purposes. Once this plan was agreed on between KSU and the FAA, the NOTAM was reviewed and accepted by Salina Airport Authority.
- Once the demonstration concluded, KSU met with the members of the Salina Airport and ARFF, that participated in a debrief of the day's events; from the ARFF perspective, the communication from the RPIC that was given to ARFF #1 and #4 by the ARFF personnel located with the RPIC were not clear. If a demonstration of this type were to occur again, the communication procedures would need to be discussed beforehand to ensure the relevant information was given in a clear and concise manner with predetermined language and sequencing.
- During KSU's demonstration, the ability to send the UAS video feed into the ARFF truck would be an added benefit. At times, the driver is the only crew member on the scene until other units arrive. This individual has several priorities ahead of communicating with a UAS operator. Sending the live feed to the truck's interior would increase the driver's situational awareness.

10 CONCLUSIONS

This research successfully identified and assessed the gaps in knowledge about the use of UAS on and around airport surfaces. The lack of information about on airport operations identified in the literature review, when combined with the information from the FAA's William J. Hughes Technical Center about what research they were conducting, provided the research team with a solid basis for the selection of three, non-duplicative, use cases for this research. The selected use cases were an emergency response to an accident on a runway, a building inspection, and an operation of a large UAS from a runway. These three use cases allowed the team to compare and contrast the hazards and potential mitigations associated with the use cases during the Safety Risk Analysis and develop risk matrices following FAA Order 8040.6 that supported the team's DroneZone or COA Application Processing System submissions.

The key findings from the safety analyses are: 1) the SRA risk matrices developed following FAA Order 8040.6 guidance were very similar in the hazards identified and potential mitigation strategies across the three use cases, 2) the safety documentation developed during the SRM process was sufficient for FAA evaluators to successfully analyze the risk of the operations and grant flight permissions for each case, and 3) the research team encountered several situations where the documentation or process to obtain flight approvals was not clear and required high-level FAA input to determine the route to a flight approval.

Some key findings from the ground and flight testing are: 1) there are challenges to on airport operations that will not be discovered until a team attempts to conduct an operation, such as when the UND team discovered the electromagnetic interference at their launch site or the UAF team discovered that quick differential breaking is essential to safe taxiing on a slippery surface, 2) GPS uncertainties can be significant during low altitude operations near buildings and other infrastructure common in an airport environment, 3) real-time feeds of video can enhance communication between parties participating in an operations, 4) communications protocols between ATC, the RPIC, and other parties should be coordinated prior to operations, 5) ATC needs more operational awareness of the UAS potentially flying on airport at the same time to ensure deconfliction, 6) aircraft and systems must be modified to operate in the conditions they may experience on airport, and 7) operators are not clear on the required documentation or processes to obtain the documentation for operations on airport.

The NMSU UAS FTS provided background, descriptions of operation experience, best practices, roles and responsibilities, and lessons learned from the almost 20-year history of the New Mexico State University's operations of large UAS from a non-towered General Aviation airport. Based on ~330 flights of large UAS at un-towered airports and mature Standard Operating Procedures SOP that are living documents, all phases of the planning and operational arc are discussed. The safety focus for these operations begins with a risk-based assessment of the vehicle and operations, and is through all phases of the flight operations and contingencies to ensure safe integration with crewed aviation.

The research team developed some key recommendations for consideration by the FAA for improving the ability of UAS to integrate into the airport environment. They include:

- The development of better guidance for operators requesting UAS waivers. The team recommends a series of questions be developed that ATC, Airport Managers, and UAS operators would mitigate risk together.
- The integration of UAS flight data into ATC systems in some form could help ATC personnel obtain greater situational awareness to manage complex traffic operations between UAS and crewed aircraft.
- Information submitted to LAANC is not integrated with ATC. ATC may desire to receive real-time data of UAS movement on and around airports.
- Minimizing GPS and electromagnetic interference in the airport environment through airport design, analysis and documenting existing interference, and/or UAS operator analysis of operational conditions where interference could be an issue would provide a benefit for UAS operations. Using SRA documentation, develop a standard list of potential risks associated with flights on and around airports that include risks that must be addressed at a minimum for a waiver to be approved.
- PRAs should be conducted to better identify risk likelihood and saturation levels for UAS operating on and around airports with crewed aircraft.
- Development of expectations for pilots to understand aircraft programmed/automatic response to a given failure and understand time needed react to a given emergency should the automation fail.

This research showed that operators need clear guidance on what permissions, both ground and flight, must be obtained from the FAA and FCC prior to flying a UAS on or around airport surfaces. The FAA should consult with ASSURE, UAS Test Sites, BEYOND sites, and others to capture the challenges they discover as they integrate UAS into the airport environment and use them to develop flight approval check lists, disseminate successful risk management strategies, help develop policies and procedures, change regulations, and or inform standards that will advance the safe operation of UAS on and around airport surfaces.

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12 APPENDIX A - PARTICIPANTS

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13 APPENDIX B - EMERGENCY RESPONSE SURVEILLANCE (SAFETY AND SECURITY) CASE STUDY

A31 Case Study #3

Emergency Response Surveillance (Safety and Security)

1) Executive Summary

This document reflects a high-level overview of a use case for UAS in the role of emergency response surveillance on airports. A safety analyses will be performed to assess the risks associated with UAS operations on and around the airport surface. Upon approval from the FAA, a tabletop exercise and sUAS flight for the implementation of UAS by an airport authority for use in emergency response surveillance will be conducted to validate the identified risk and risk mitigation strategies.

2) Introduction

UAS offer increased capabilities for airports to support emergency response operations. This is especially true in instances where accidents and other emergency scenarios may require the optimal employment of airport resources, such as fire, hazmat, and/or other dedicated personnel. According to the NASEM's ACRP Guidebook 212 titled, *Airports and Unmanned Aircraft Systems, Volume 3: Potential Use of UAS by Airport Operators (2020)*, a proposed purpose of UAS use is to "supplement on-site emergency personnel, to augment existing capabilities, or to provide new capabilities such as mobile lighting, surveillance, or appropriate resource allocation." The proposed outcomes and improvements of using UAS for on-site emergency repose include "mobile and indefinite lighting sources to improve crew visibility and illumination at night, and airports can quickly mobilize UAS surveillance platforms to understand the scope of the emergency and allocate appropriate resources." Further exploration of UAS in the emergency response role will be considered to identify the potential to increase the capacity of airports to (1) respond to emergency scenarios, and (2) add to airports' emergency response toolset.

3) Proposed Solution

- ***Emergency Response Surveillance*****.** Kansas State University and the University of Alabama Huntsville will develop a case study for the use of UAS to support emergency response (safety and security) operations at Salina Regional Airport (SLN), a class D airport.
- Benefits of Use Case Study
    - This case study will provide an opportunity to address multiple elements of operating UAS in and around airports with regards to identifying and mitigating risk related to:
        1. UAS operations on the ground at airports, including existing autonomous missions,
        2. Operations near manned aircraft,

3. Communication with UAS operators (if necessary), and with Air Traffic (AT) services, a benefit to both user groups,
4. Identifying risks related to operations in and around airport,
5. Identifying any lack of infrastructure to support UAS use in and around airports,
6. Identifying barriers related to regulations, polices, with the various entities involved in process, including both ATC and airport operations, and
7. Identifying education or outreach activities that are required for on-airport operations.

- Support this case study solution with sufficient evidence.

  This case study will provide an opportunity to explore how UAS integrate into emergency scenarios that take place within controlled (Class D) airspace. Furthermore, this case study will explore aspects of airspace integration in off-nominal scenarios where ATC and/or ground personnel may introduce and/or mitigate hazards that may not otherwise be present in the environment.

  As shown in Appendix A, SLN is a towered Class D airport. This environment is ideal for evaluating emergency and disaster response operations with UAS on airports, as it enables operations in controlled airspace. Appendix B shows a diagram of SLN, which consists of a series of runways ranging in length from 3648 feet to 12,301 feet. These runways enable the research team to capture several plausible disaster and emergency scenarios, including general aviation accidents to the (notional) crash of a large transport aircraft in an environment where ATC and air traffic must be considered.

4) Strategy

Specific strategies for accomplishing the proposed solution. The team will:

- Conduct a tabletop exercise and sUAS flight demonstration with the Salina Airport Authority to identify how and where UAS would be implemented into their emergency response plan(s) and operations. As part of these exercises, Kansas State University will perform a hazard assessment to identify initial hazards and barriers to safe operations using a set of baseline assumptions determined in concert with airport emergency response personnel.
- Conduct a tabletop exercise and sUAS flight demonstration, where the following scenarios will be considered:
  1. General aviation incident (no injuries)
  2. General aviation accident (injuries)
  3. Commercial airline accident (injuries)
- Perform a hazard assessment to identify key considerations for airspace integration and the safe operation of UAS by airport personnel.

5) Timeline of Events

While timelines are often impacted by various entities outside the oversight of the Universities, the intent is to provide the following sequence of events through August 2022:

- November 2021 - Complete Use Case Development and obtain approval of FAA Sponsors to begin the safety risk management process for tabletop exercise and sUAS flight for use case operation.
- February 2022 - Complete the tabletop Safety Risk Management (SRM) process, identifying the hazards and mitigations proposed use case.
- April 2022 – Meet with Airport Operations and Airport Management to run through the Tabletop exercise to validate the proposed mitigations and conduct a sUAS flight.
- October 2022 - Final Report - Provision of a comprehensive report that covers the entirety of these efforts.

6) Appendices

Appendix A – Salina Regional Airport (SLN) Class D Airspace.
Appendix B – Airport Diagram for Salina Regional Airport (SLN).

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Appendix A

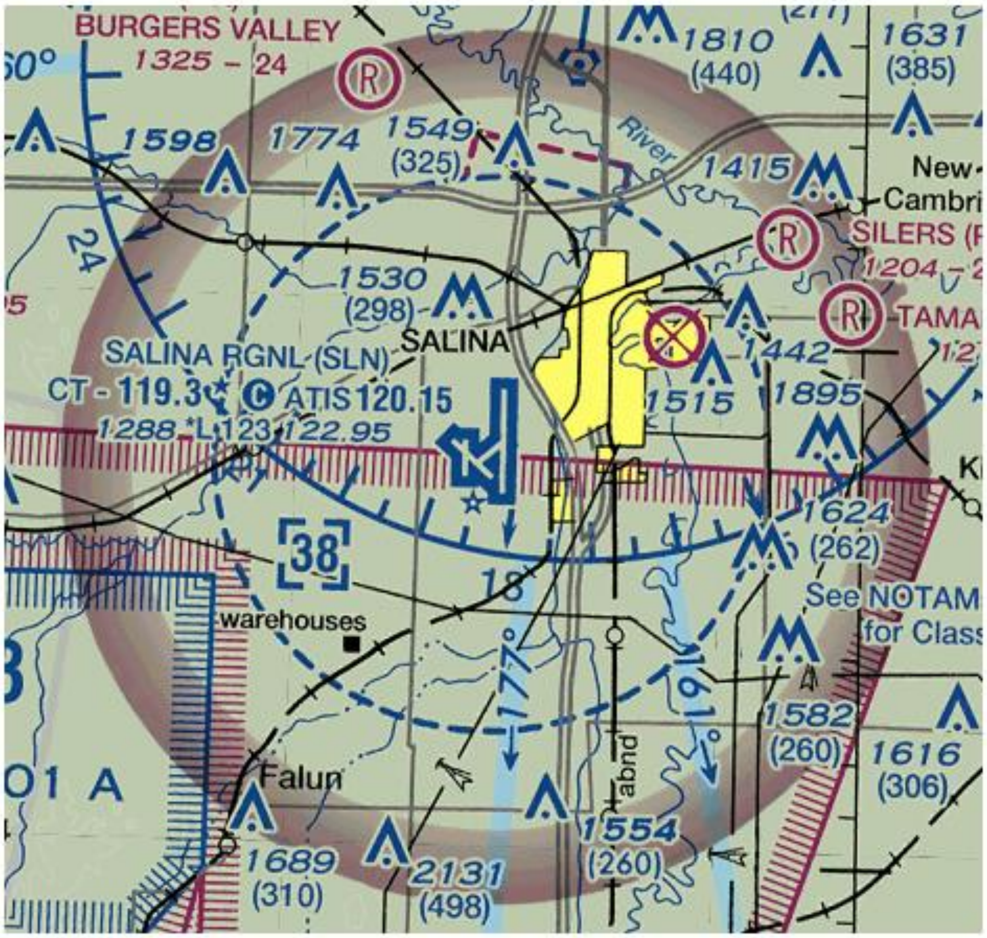


Figure 1. Salina Regional Airport (SLN) Class D Airspace.

Appendix B

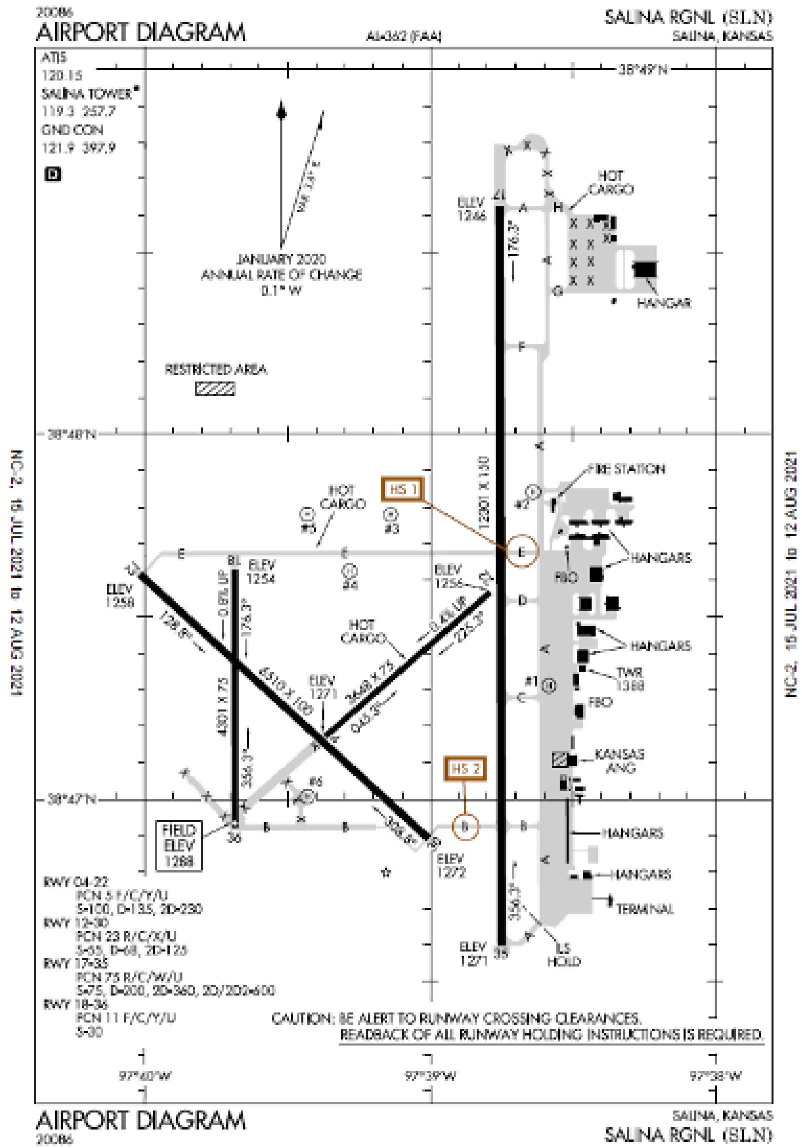


Figure 2. Airport Diagram for Salina Regional Airport (SLN).

14 APPENDIX C – GRAND FORKS INTERNATIONAL AIRPORT – SAFETY RISK ASSESSMENT FOR INFRASTRUCTURE ASSESSMENT – LANDSIDE

Safety Risk Assessment - A31 Airport Ops

Technical Issue UAS - TI

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Controls	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	UAS Electrical Failure	A complete power failure of the UAS system via the onboard battery would cause the aircraft to go into uncontrolled flight. The aircraft could "tumble" to the surface with no aerodynamic benefit. This potentially could cause a hazard to persons or infrastructure on the ground.	1) Preflight setup checks are preformed by the RPIC IAW DJI checklist. 2) Electrical power is provided by the onboard LiPo battery. 3) The aircraft calculates how much battery it takes to return home based on distance away from the controller. Once this BINGO battery estimate hits the aircraft will automatically return home. 4) At 10% battery remaining the aircraft will attempt an automatic landing wherever it is located. 5) These are Intelligent Flight batteries that if a fault is detected prior to takeoff it will prevent takeoff from occurring. 5) Flights will not be conducted above non-participating people.	4C	DJI uses "smart" batteries that self monitor the status. Batteries are self checked on post,(startup). All cells are meausured for voltage and compared to each other. Example, if cells differ by more then 5%, the system will not allow that battery to be used and will not allow the take off status	4C	Under UND's FAA accepted SMS Program, established safety assurance processes will be utilized to ensure UND is operating under the limitations of part 107. The controls are effective at producing the resultant risk or less risk. If the risk is higher than expected or if additional risk is identified through the safety assurance process then additional mitigations or corrective actions will be made to reduce the risk to the lowest practical means. The SRA process falls under the oversight of the UAS Director and Process Owner.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Flight Control Failure or Malfunction	A flight control failure could result in the potential loss of controlled flight and loss of the aircraft.	1) Aircraft Pre-Flight check for airworthiness is performed by the RPIC prior to every flight. 2) Additionally adhering to part 107 rules of never flying over non-participants. 3) Prior to flight, aircraft are dispatched through AIMS which maintains the aircraft records, inspections and current flight status. Aircraft are maintained in an environmentally controlled facility. 4) Systems are checked for continuity and performance prior to every launch.	2E	Risk at lowest practical level, no additional risk mitigations are needed.	2E	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Flight Control Error or Malfunction	As stated above	As stated above	2E	Risk at lowest practical level, no additional risk mitigations are needed.	2E	As stated above.

d. The communications link between the aircraft and the control station does not work as expected: Within your ConOps, consider the consequences of the communications link between the aircraft and the operator not working as expected. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Poor Communication (C2) Link between Aircraft and GCS	Poor communications could possibly lead to "Lost Link" procedures If the C2 link drops out, the aircraft is in an "Uncommented State" and will exercise the "Lost Link" procedure. If obstacles on the ground at the predetermined landing area the onboard obstacle detection will divert the aircraft around any obstacle. The aircraft will continue to remain stable in flight during a loss of C2 Link.	1) During the preflight, communications signal strength is monitored via the controller. 2) The RPIC is also monitoring airspace and if able to communicate with Tower as needed. The VO makes sure there are no airspace conflictions with the ability to communicate with the RPIC for situational awareness. 3) All flights are to be conducted within 300 ft. of the RPIC. Keeping close proximity will prevent signal degradation.	4D	Risk at lowest practical level, no additional risk mitigations are needed.	4D	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Poor Communication (C2) Link between Aircraft and GCS due to Frequencies Interference	Poor communications could possibly lead to "Lost Link" procedures If the C2 link drops out, the aircraft is in an "Uncommented State" and will exercise the "Lost Link" procedure. If obstacles on the ground at the predetermined landing area the onboard obstacle detection will divert the aircraft around any obstacle. The aircraft will continue to remain stable in flight during a loss of C2 Link.	Frequencies are in the ISM bands and are able to except interference. Should communication get disrupted, lost link logic would take control, air adheres to altitude restrictions set by the RPIC prior to flight and navigate back to the home point.	4D	As stated above	4D	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Sensor Failure during flight.	Should the UAS Sensor System fail or malfunction, the operator would lose benefit of visual orientation, resulting in a loss of forward viewing during flight.	1) Video system is checked as part of the preflight checklist. 2) Operations would cease if the system showed any signs of degradation simply due to the point of the mission. 3) Should the sensor, (Video System) fail, this could be a cause for disorientation or distraction for the operator. The aircraft would continue to operate normally with no ill effects to the safety of flight. The RPIC would be able to continue flight using electronic observation on the controller and visual observation. They will be able to perform a normal controlled recovery of the aircraft.	5D	Within line of sight operations don't require a working sensor to safety recover the aircraft.	5D	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Engine Failure	Should the engine fail in flight the operator would be required to find the most suitable sight for landing within the time allotted for battery life to power the autopilot and flight controls. Due to erratic flight with engine failure, the emergency landing results in a hard landing damaging the UAS or property.	1) Aircraft airworthiness is performed by the RPIC prior to every flight. 2) The RPIC is also monitoring airspace and would have access to contact ATC. 3) The VO is makes sure there are no airspace conflictions with the ability to communicate with the RPIC for situational awareness. 4) Operations of people is prohibited.	4D	Task simply requires the RPIC to make best path decision to avoid damaging people or property.	4D	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Controller Software Failure	Should the GCS Controller system fail in its entirety, the aircraft would go to the Lost Link Logic procedure as explained previously and auto land uncommand at the takeoff point.	1) During the controller failure the aircraft will climb to predetermined AGL set on preflight, return to the takeoff location, and land. The obstacle avoidance on the aircraft will divert its path if an obstacle is detected. 2) As part of the Preflight, the system uses a checklist to start up and confirm the system is operating properly prior to flight.	4D	Software is proprietary to DJI. RPIC relies on DJI to provide updates as necessary and checked during aviable WiFi.	5D	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	GPS Navigation Failure	The only Navigation failure to consider is GPS failure and during this failure, this is still controllable aircraft in VLOS operation. This would result in momentary distraction of the RPIC.	1) During the preflight, GPS signal to noise ratio is monitored for the health of the system and checked through the flight. The system typically maintains connections with 10 or more satellites. Pilots are capable of flying the aircraft in "ATTI Mode" which is when the aircraft will operate as normal just without the GPS. 2) During preflight and flight, the GPS status is continuously display and monitored. Should the aircraft experience poor GPS solution or even GPS failure, the Controller announces "ATTI Mode" and a visual cue on the controller pops up. During a GPS failure, the RPIC transitions to "Visual References" on through the video camera system to make assist in choices as to where the aircraft should be sent. The aircraft is also able to be flown visually. Aircraft control is maintained all the way to the ground. 3) The RPIC is also monitoring airspace for traffic avoidance. 4) The VO is making sure there are no airspace conflictions while communicating with the RPIC for situational awareness.	5D	Risk at lowest practical level, no additional risk mitigations are needed.	5D	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	No DAA	During automation, the system has obstacle avoidance on board the aircraft and it will only see objects within 10 ft. There is the possibility of not remaining well clear with a Crewed aircraft with in the aerodrome creating a hazardous condition.	1) Use of a VO coupled with a communications to maintain "Clear" during all phases of flight. The RPIC will have a hand held VHF radio and monitoring KGFK tower. 2) Tower will be able to communicate any concerns either through the VHF radio or the RPIC's cell phone (the phone number being given to tower prior to operations) 3) On the GCS controller ADSB data is also being displayed to aid in situational awareness. 4) Aircrews are training annually in VO responsibilities and CRM awareness. Training is track in AIMS. 5) All RPIC's are of course rated part 107 holders with 500 hours of experience in sUAS. 6) RPIC are commercially rated in crewed pilots with an in depth knowledge of KGFK airspace to include traffic pattern operations. The crew understands common phraseology for pilots.	3D	Historical ADSB data for Grand Forks airport has been obtained and is being used to analysis hours where airport is most busy as well as to ensure the UAS only flys in areas that historically have little to no activity over the landside portion of the airport below 100ft.	3E	As stated above.

k. Airframe structural damage undetected before flying, for instance, from a previous rough landing: Within your ConOps, consider the consequences of the airframe having structural damage which has not been detected before flying. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
TI	Structure Failure	An airframe failure in flight could lead to an unintended crash of the airframe about the surface.	1) Aircraft airworthiness is performed by the RPIC prior to every flight. 2) Additionally adhering to part 107 rules of never flying over non-participants. 3) During preflight the aircraft is inspected IAW the DJI preflight checklist. Airframe, fasteners, attachment points, control surfaces, control surface hinge points, lights, camera system, engine for performance and run up and pitot static system are all inspected for proper operation and response.	4D	Risk at lowest practical level, no additional risk mitigations are needed.	4D	As stated above.

Human Error (HE)

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	UAS not maintained by competent and/or proven entity	An airframe, engine or component failure in flight could lead to an unintended crash of the airframe about the surface.	1) All aircraft are purchased new from the manufacture. 2) Stored in an environmentally controller building. 3) Pre and Post flights are conducted by trained instructors every time. 4) During preflight the aircraft is inspected IAW the DJI preflight checklist. Airframe, fasteners, attachment points, control surfaces, control surface hinge points, lights, camera system, engine for performance and run up and pitot static system are all inspected for proper operation and response. 5) Designed personnel are identified to return damaged aircraft to service. When something needs repair, aircraft discrepency forms are completed and the a/c are not returned to service until they have been properly repaired.	5D	Risk at lowest practical level, no additional risk mitigations are needed. Flights will not be conducted within navigatable airspace for manned aircraft within 100' airport buildings.	5D	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	UAS not inspected	An airframe, engine or component failure in flight could lead to an unintended crash of the airframe about the surface.	1) All aircraft are purchased new from the manufacture. 2) Stored in an environmentally controller building. 3) Pre and Post flights are conducted by trained instructors every time. 4) During preflight the aircraft is inspected IAW the DJI preflight checklist. Airframe, fasteners, attachment points, control surfaces, control surface hinge points, lights, camera system, engine for performance and run up and pitot static system are all inspected for proper operation and response. 5) Designed personnel are identified to return damaged aircraft to service. When something needs repair, aircraft discrepency forms are completed and the a/c are not returned to service until they have been properly repaired.	5D	Risk at lowest practical level, no additional risk mitigations are needed. Flights will not be conducted within navigatable airspace for manned aircraft within 100' airport buildings.	5D	As stated above.

c. UAS consistency with ConOps cannot be ensured: Within your ConOps, consider the consequences of a UAS consistency with ConOps cannot be ensured. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	UAS consistency with ConOps cannot be ensured	Inconsistency with the ConOps creating confusion during operations leading to human error and possible accident related to CFIT	1) Pre-brief of the plan will take place prior to takeoff with all crew members. 2) Site survey, has been completed and set up is completed IAW UND checklist. 3) The RPIC is an Instructor who has been standardized in the aircraft and controller systems. 4) Discussion are centered around each individual roles and responsibilities, sterile flight deck, VO positions and site security and safety. 5) Aircraft flights have be consistent with little to no concerns. 6) Briefing are held before flight, prior to launch to announce settings and flight paths.	5C	Risk at lowest practical level, no additional risk mitigations are needed.	5C	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	Failure to maintain or manage altitude	Creating hazardous situation with improper altitude control leading to CFIT	1) During the preflight the system allows safe settings to include altitude limitations. The altitude limit will be set to 100 agl. The aircraft will adhere to this via its GPS altitude or if that fails its barometric altitude. The system understand DTED values related to MSL. 2) Flight will be conducted with an experienced and standardized RPIC. Altitude limits will be set to a "no higher than" altitude on the GCS controller. RPIC and VO will observe aircraft height and make necessary corrections as needed.	5C	Risk at lowest practical level, no additional risk mitigations are needed.	5C	As stated above.
HE	Failure to maintain or manage altitude	Creating hazardous situation with improper altitude control leading to flight outside of the vertical limits	1) During the preflight the system allows safe settings to include altitude limitations. The altitude limit will be set to 100 agl. The aircraft will adhere to this via its GPS altitude or if that fails its barometric altitude. 2) Flight will be conducted with an experienced and standardized RPIC. Altitude limits will be set to a "no higher than" altitude on the GCS controller. RPIC and VO will observe aircraft height and make necessary corrections as needed.	5C	Risk at lowest practical level, no additional risk mitigations are needed.	5C	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	Incorrect Input for aircraft control	Creating hazardous situation with improper altitude control leading to CFIT	1) During the preflight the system allows safe settings to include altitude limitations. The altitude limit will be set to 100 agl. The aircraft will adhere to this via its GPS altitude or if that fails its barometric altitude. 2) Flight will be conducted with an experienced and standardized RPIC. Altitude limits will be set to a "no higher than" altitude on the GCS controller. RPIC and VO will observe aircraft height and make necessary corrections as needed.	5C	Risk at lowest practical level, no additional risk mitigations are needed.	5C	As stated above.
HE	Incorrect Input for aircraft control	Creating hazardous situation with improper altitude control leading to flight outside of the vertical limits.	1) During the preflight the system allows safe settings to include altitude limitations. The altitude limit will be set to 100 agl. The aircraft will adhere to this via its GPS altitude or if that fails its barometric altitude. The system understand DTED values related to MSL. 2) Flight will be conducted with an experienced and standardized RPIC. Altitude limits will be set to a "no higher than" altitude on the GCS controller. RPIC and VO will observe aircraft height and make necessary corrections as needed.	5C	Risk at lowest practical level, no additional risk mitigations are needed.	5C	As stated above.

f. The crew does not monitor the flight as indicated in the ConOps. For instance, the crew does not use binoculars to scan the sky in order to detect intruders, whereas this means was included in the ConOps: Within your ConOps, consider the consequences of the crew not monitoring the flight as indicated in the ConOps. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	Loss of aerodrome situational awareness	Creating a hazard not monitoring both systems and aerodrome for conflicting traffic leading to a not remaining well clear with a crewed aircraft.	1) Emphasis is heavily place on the roles and responsibilities of each individual to perform assigned duties. 2) During flights, a VO and RPIC are monitor the airspace for both aircraft activity and drone flight. 3) Through the controller, the RPIC is responsible for monitoring activities with the aircraft and maintaining a instrument scan. 4) Radio is tuned into the Tower for KGFK traffic and radio calls are monitored. 5) VO responsibilities are discussed prior to operations. 6) Additionally the RPIC is also a rated Commercial pilot with substantial knowledge of KGFK's airspace and operations.	5C	Risk at lowest practical level, no additional risk mitigations are needed.	5C	As stated above.

g. The visual observer and the RPIC do not coordinate as indicated in the ConOps: Within your ConOps, consider the consequences of inappropriate coordination as indicated in the ConOps. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	Communication failure between RPIC and VO	Human error to give the wrong turn information's possibly causing a situation where a traffic conflict could occur creating a violation of well clear or NMAC	1) Communications between RPIC and VO are pre-briefed and trained.-Instructions for conflict management are given in cardinal headings. 2) Traffic is identified to the North. VO calls out, "***Traffic North***". From the RPIC standpoint, the aircraft is moved in the best choice of action to avoid a conflict which in most case is a quick decsent. 3) RPIC and VO are both observing. Visibility for flight is greater then what will be required for both the VO and RPIC time to respond.	5C	Risk at lowest practical level, no additional risk mitigations are needed.	5C	As stated above.

h. Remote crew unfit to operate (impaired by drugs/alcohol, etc.): Within your ConOps, consider the consequences of remote crew unfit to operate. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
HE	Remote crew unfit to operate (impaired by drugs/alcohol, etc.)	Student or instructor failing to identify as IMSAFE degrading situational awareness resulting in well clear violation.	1) UND has a mature Safety Policies and Procedures (SP&P). Instructor and students alike are required to meet and follow the SP&P, which include duty times, max contact time, drug testing, weather minimums, a Supervisor of flight monitoring flight activity, similar to FAR Part 141 requirements for pilot schools, and alcohol hourly limits. 2) Prior to flight each instructors and students is required to sign a dispatch slip attesting to fitness for flight. 3) Crew will include RPIC and visual observer reducing likelihood that situational awareness will not be lost. 4) UND Aerospace has an FAA accepted SMS program under the SMS Voluntary program. The program specifically lists our Part 141 and Part 145 certificates but expands to our entire organization (system) which includes all UAS Operations. Our SMS manual includes process to manage risk as well as monitor those processes through our safety assurance processes. 5) All RPICs are rated Commercial pilots with min of 2 years of experience in the professional industry and understand the importance of flight safety related to being impaired.	3D	Risk at lowest practical level, no additional risk mitigations are needed.	3D	As stated above.

Adverse Operating Conditions (AC)

a. Remote crew not trained in flights in adverse weather conditions. For example, not being able to determine when high winds occur nor understanding response of aircraft to high winds: Within your ConOps, consider the consequences of remote crew not trained in flights in adverse weather conditions. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
AC	Adverse Weather conditions	Adverse weather conditions causing an emergency landing at an unplanned location.	1) Weather is closely monitored during all operations. Winds for flight are 17kts. 2) UND has a mature Safety Policies and Procedures (SP&P). Instructor and students alike are required to meet and follow the SP&P, which include weather minimums, a Supervisor of flight monitoring weather activity, similar to FAR Part 141 requirements for pilot schools. 3) The Mavic 2 Pro is capable of landing at almost any location. The accuracy of the aircraft landing would allow the RPIC to safety land with no injury or damage infrastructure. 4) Weather forecast are used from KGFK determine the probability of operations. During dispatch, the SOF uses established wind limitations that are reduced from the OEM limitations.	5B	Risk at lowest practical level, no additional risk mitigations are needed.	5B	As stated above.

b. External supporting services to UAS are not consistent with ConOps indications. For instance, if certain weather forecast services are assumed to be provided, the external service does not provide weather information: Within your ConOps, consider the consequences of external supporting services to UAS not consistent with ConOps indications. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
AC	Unavailable Weather Forecast	Adverse weather conditions causing an emergency Landing.	1) Weather is closely monitored during all operations. Winds for flight are 17kts. 2) UND has a mature Safety Policies and Procedures (SP&P). Instructor and students alike are required to meet and follow the SP&P, which include weather minimums, a Supervisor of flight monitoring weather activity, similar to FAR Part 141 requirements for pilot schools. 3) The Mavic 2 Pro is capable of landing at almost any location. The accuracy of the aircraft landing would allow the RPIC to safety land with no injury or damage infrastructure. 4) Weather forecast are used from KGFK determine the probability of operations. During dispatch, the SOF uses established wind limitations that are reduced from the OEM limitations. 5) Forecasting materials like the Helicopter Emergency Medical Services Tool along with local weather networks, ATIS is used for onsite decision making to launch or recover the aircraft.	5E	Risk at lowest practical level, no additional risk mitigations are needed. KGFK has is own reporting station with both ADDS and ATIS information.	5E	As stated above.

c. No established limits for operations such as a maximum wind speed or precipitation: Within your ConOps, consider the consequences of no established limits for operations such as a maximum wind speed or precipitation. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
AC	Standard Operating Procedures	No SOP's established could cause a situation where the crew launch into adverse conditions.	1) UND has a mature Safety Policies and Procedures (SP&P). Instructor and students alike are required to meet and follow the SP&P, which include duty times, max contact time, drug testing, weather minimums, a Supervisor of flight monitoring flight activity, similar to FAR Part 141 requirements for pilot schools 2) Weather limitations are posted and prior to each flight, the SOF dispatches the aircraft base on adherence to these limitations. 3) UND Aerospace has an FAA Accepted SMS program under the SMS Voluntary program. The program specifically lists our Part 141 and Part 145 certificates but expands to our entire organization which includes all UAS Operations. Our SMS manual includes process to manage risk as well as monitor those processes through our safety assurance processes. 4) Weather limitation are set to meet or exceed VFR requirements. Most limitations are set with a safety margin that is in excess of OEM operating limitations.	5E	Risk at lowest practical level, no additional risk mitigations are needed.	5E	As stated above.

Unable to see and avoid (SA)

a. How the Remote Pilot in Command (RPIC) will be able to continuously know and determine the position, altitude, attitude, and movement of his/her small unmanned aircraft (sUAS) or drone and ensure the sUAS or drone remains in the area of intended operation without exceeding the performance capabilities of the command and control link.

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
SA	Situational awareness related to position	With no situational awareness, the UAS could hit other aircraft.	1) All instructors/students participating are properly trained to act as a VO. 2) This requires coordination between both crewmembers to accomplish the simple task of "see and avoid". The VO is responsible to maintain well clear aircraft about the UA's trajectory. That said, the RPIC's goal is to simply fly the aircraft using visual as well as electronic observing/monitoring systems or "digital" airspace via the DJI Controller. 3) The VO will call out traffic as they become a conflict with cardinal heading and then give a heading and altitude call to avoid a conflict, example, "Traffic north turn eastbound and descend". 4) Before meeting on site, crew members are briefed on the environment prior to flying there. 5) During the flight, the RPIC is always aware of the aircraft's position in space due to real time positioning on the moving map display. At this point, the instructor pilot manages the flight IAW information based on an instrument scan, internet traffic data and VO maintain well clear throughout the flight.	2E	Risk at lowest practical level, no additional risk mitigations are needed.	2E	As stated above.

SA	Situational awareness related to position	With no situational awareness, the UAS could hitground targets causing a hazard.	1) All instructors/students participating are properly trained to act as a VO. 2) This requires coordination between both crewmembers to accomplish the simple task of "see and avoid". The VO is responsible to maintain well clear aircraft about the UA's trajectory. That said, the RPIC's goal is to simply fly the aircraft using visual as well as electronic observing/monitoring systems or "digital" airspace via the DJI Controller. 3) The VO will call out traffic as they become a conflict with cardinal heading and then give a heading and altitude call to avoid a conflict, example, "***Traffic North***". 4) Before meeting on site, crew members are briefed on the environment prior to flying there. 5) During the flight, the RPIC is always aware of the aircraft's position in space due to real time positioning on the moving map display. At this point, the instructor pilot manages the flight IAW information based on an instrument scan, internet traffic data and VO maintain well clear throughout the flight.	2E	Risk at lowest practical level, no additional risk mitigations are needed.	2E	As stated above.

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
SA	Position related to another aircraft	Maintaining traffic separation during flight from another aircraft as to avoid a collision hazard.	1) Traffic pattern data has been derived to showcase the traffic pattern altitudes and locations. The areas to be flown will stay well clear of the Traffic Pattern altitudes with a maximum height set to 100 ft. agl. 2) Various simulations have been conducted for various emergencies to determine if well clear could be violated should a GPS failure or other emergency happen. Those buildings that present a greater risk will be limited regarding the time those flights will occur to align with low traffic hours. 3) A portable radio will be on site with the RPIC to monitor ATC calls. ATC will be able to get ahold of the RPIC via phone call or radio in the event of an emergency. The aircraft will have a height ceiling of no more than 100 ft. agl set during preflight. 4) Before meeting on site, all crew members are briefed on the environment prior to flying there. The RPIC will be seasoned with over 100 hours of flight time during our operations and the roles and responsibilities are well understood. During the flight, the RPIC is always aware of the aircraft's position in space due to real time positioning on the moving map display and visually. At this point, the pilot manages the flight IAW information base on instrument scan, internet traffic data and VO maintain well clear throughout the flight.	2D	1) Various simulations have been conducted for various emergencies to determine if well clear could be violated should a GPS failure or other emergency happen. Those buildings that present a greater risk will be limited regarding the time those flights will occur to align with low traffic hours. 2) ADS-B data has been collected to show historical data regarding best times to fly as well as likelihoods of an aircraft penetrating below 100ft agl on the landside of the airport.	2E	As stated above.

UAS Operations (OU)

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

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
UO	Beyond the system limitations of the VO's ability to see the aircraft	Flying beyond the system ability to communicate with the aircraft or the VO's line of sight to see and avoid other aircraft resulting in a NMC.	1) The system has the ability to communicate well beyond visual range. It is designed to maintain communications up to 5 NM with the Omni directional antenna. 2) The VO's at all time maintains verbal communications with the RPIC . If unable to pick of the aircraft, the VO directs the RPIC to move the aircraft into and over a known locations. All flights will be conducted within a lateral distance of 1000 ft. of the RPIC. In addition to this, 1 Nautical Mile is well within the visual acuity of any VO maintaining eye sight corrected for driving standards. Additionally keeping the aircraft close to the operator aids in maintaining line of sight and making adjustments to flight path.	2E	Risk at lowest practical level, no additional risk mitigations are needed.	2E	As stated above.

c. Emergency Response Plan: It exists, but it has not been tested previously: Within your ConOps, consider the consequences of an Emergency Response Plan not having been tested previously. Would any credible consequence result in damage or harm to people on the ground, damage to critical infrastructure or to other property meeting FAA 107.9, a collision with a manned aircraft, or loss of control of the aircraft?

Hazard Category	Hazard Condition	Outcome-Harm	Existing Conditions	Risk	Additional Mitigations	Resultant Risk	Controls Effective
UO	Untested Response Plan	Untested response plan resuting in delay in response to a emergency.	1) UND Flight operations has a robust Emergency Response plan as required by our FAA accepted SMS program and the emergency response plan has been demonstrated jointly with the Grand Forks Airport as well as conducted during tabletop exercises. Currently, the Emergency Response Plan is initiated by the SOF and if activated, brings the Director of Aviation Safety and all SMS process owners and managers together to response in unison. The response plan is located at the GCS and also is available online to students and instructors. Should the need arise, the RPIC or any crew member on site can start ERP call 911 in the event someone is hurt and then contact SOF who will activate the plan by working through the ERP guidance. 2) Additional Emergency simulations have been done in relation to intended buildings tthat will be inspected to detemine the impact of lost of communication, or GPS failure. These results have assistant in the development of the conops and when and what buildings will be inspected.	2E	Risk at lowest practical level, no additional risk mitigations are needed.	2E	As stated above.

15 APPENDIX D - COA - FAIRBANKS INTERNATIONAL AIRPORT

Unmanned Aircraft System COA
Public Agency
2022-WSA-10342-COA

Page 1 of 9

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION (FAA)

CERTIFICATE OF WAIVER OR AUTHORIZATION (COA)

ISSUED TO
University of Alaska Fairbanks, Geophysical Institute — Part 91

ADDRESS
2160 Koyukuk Dr.
Fairbanks, AK 99775

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate, except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED
Operation of the Griffon SeaHunter and DRS Sentry, unmanned aircraft system (UAS) in Class D, E, and G airspace at or below 10,000 mean sea level (MSL) within the boundaries depicted in Attachment 1 map, and coordinates depicted in Attachment 2, under the jurisdiction of Fairbanks Airport Traffic Control Tower/Terminal Radar Approach Control (FAI), Ladd Army Air Field (FBK), and Anchorage Air Route Traffic Control Center ZAN. See Attachment 1.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE

N/A

STANDARD PROVISIONS

1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the FAA or of any state or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein.
4. This certificate is nontransferable.

Note: This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any state law or local ordinance.

SPECIAL PROVISIONS

Special provisions A through H are set forth on the reverse side hereof.

This certificate is effective from May 2, 2022 to May 1, 2024 and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.

BY DIRECTION OF THE ADMINISTRATOR

ADAM A VETTER — Digitally signed by ADAM A VETTER Date: 2022.05.02 14:35:17 -07'00'

FAA Western Service Area (Region)	Adam Vetter (Signature)
May 2, 2022 (Date)	Tactical Operations Manager (Title)

FAA FORM 7711-1 (7-74)
UAS COA Attachment

Version Date: December 2021

Purpose: To prescribe UAS operating requirements in the National Airspace System (NAS) for the purpose of Public Aircraft Operations. The holder of this COA will be referred herein as the "Proponent."

Public Aircraft

1. A public aircraft operation is determined by statutes 49 U.S.C. § 40102(a)(41) and § 40125.
2. All public aircraft flights conducted under a COA must comply with the terms of the statute.
3. All flights must be conducted per the declarations submitted in the application and as specified in the following standard/special provisions.
4. This COA provides an alternate means of complying with Title 14 CFR § 91.113(b) for unmanned aircraft operations.
5. All operations will be conducted in compliance with Title 14 CFR § 91 and the conditions of the authorization issued herein. If the operator cannot adhere to any of these requirements, a separate FAA Form 7711-2 waiver application may be required.

SPECIAL PROVISIONS

A. General.

1. All personnel connected with the UAS operation must read and comply with the contents of this authorization and its provisions.
2. A copy of the COA including the special limitations must be immediately available to all operational personnel at each operating location whenever UAS operations are conducted.
3. This authorization may be canceled at any time by the Administrator, the person authorized to grant the authorization, or the representative designated to monitor a specific operation. As a general rule, this authorization may be canceled when it is no longer required, if there is an abuse of its provisions, or when unforeseen safety factors develop. Failure to comply with the authorization is cause for cancellation. The proponent will receive a written notice of cancellation.
4. During the time this COA is approved and active, a site safety evaluation/visit may be accomplished to ensure COA compliance, assess any adverse impact on air traffic control (ATC) or airspace, and ensure this COA is not burdensome or ineffective. Deviations accidents/incidents/mishaps, complaints, etc., will prompt a COA review or site visit to address the issue. Refusal to allow a site safety evaluation/visit may result in cancellation of the COA.

   Note: This section does not pertain to agencies that have other existing agreements in place with the FAA.

5. Radiofrequency spectrum authorization is independent of the COA process and requires the proponent to obtain Federal Communications Commission (FCC) equipment certification (47 CFR Part 2, Subpart J and 47 CFR Part 87, Subpart D) and frequency licenses (47 CFR Part 87) in the Aeronautical Radionavigation, Aeronautical Mobile (Route), or Aeronautical Mobile Services, as appropriate, for the control link, ATC radios, transponders, detect and avoid systems, and navigation systems used to support this COA. For systems operating exclusively below 400 feet, and within visual line of sight, the control link equipment may be licensed under 47 CFR Part 15 (Radio Frequency Devices).

Equipment licensed under 47 CFR Part 5 (Experimental) does not provide the protection necessary for NAS operations.

B. Operations.

1. Unless otherwise authorized as a special provision, a maximum of one UA will be controlled:
   a. From a single control station; and
   b. By one pilot at a time.
2. When necessary, transit of airways and routes must be conducted as expeditiously as possible. The UAS should not plan to loiter on Domestic VOR Federal airways (Victor airways), Jet Routes, United States Area Navigation Routes (Q and T routes), or IFR and VFR Military Training Routes (IRs and VRs).
3. For flights operating on an instrument flight rules (IFR) clearance, the pilot in command (PIC) must ensure positional information in reference to established National Airspace System (NAS) fixes, navigational aids (NAVAID), and/or waypoints are provided to ATC. The use of latitude/longitude positions is not authorized, except oceanic flight operations.
4. Unless installed as part of a detect and avoid (DAA) system, the use of a traffic collision avoidance system in traffic advisory or traffic advisory/resolution advisory modes while operating an UA is prohibited.

C. Safety of Flight.

The operator or delegated representative is responsible for halting or canceling activity in the COA area if, at any time, the safety of persons or property on the ground or in the air is in jeopardy, or if there is a failure to comply with the terms or conditions of this authorization.

a. Any crew member responsible for performing see-and-avoid requirements for the UA must have and maintain instantaneous communication with the PIC.

b. Visual observers must be used at all times except in Class A airspace, active restricted areas, and warning areas designated for aviation activities, or as authorized in the special provisions. Observers may either be ground-based or airborne in a chase plane.

(1) Visual Observers:

(a) Must be able to communicate distinctly to the pilot any instructions required to remain clear of conflicting traffic, using standard phraseology as listed in the Aeronautical Information Manual when practicable.

(b) The PIC is responsible to ensure visual observers are able to see the aircraft and the surrounding airspace throughout the entire flight.

(c) The PIC is responsible to ensure visual observers are able to provide the PIC with the UA's flight path, and proximity to all aviation activities and other hazards (e.g., terrain, weather, structures) sufficiently to exercise effective control of the UA to:

- Comply with 14 CFR § 91.111, § 91.113, and § 91.115;
- Prevent the UA from creating a collision hazard; and
- Comply with all conditions of this COA.

(2) Chase Aircraft:

(a) If the chase aircraft is operating more than 1 mile laterally or longitudinally and/or more than 100 feet vertically of the UA, the chase aircraft PIC will advise the controlling ATC facility.

(b) Must remain at a safe distance from the UA to ensure collision avoidance if a malfunction occurs.

(c) Must remain close enough to the UA to provide visual detection of any conflicting aircraft and advise the PIC of the situation.

(d) Must remain within radio control range of the UA to maintain appropriate signal coverage for flight control or activation of the flight termination system, for all operations when the UA is being flown by a pilot in the chase aircraft.

(e) May be required to have communication with appropriate ATC facilities based on the operator's application or mission profile.

(f) Must maintain five statute miles in-flight visibility restrictions.

(g) Pilot/observer:

- Will not concurrently perform either observer or UAS pilot duties along with chase pilot duties unless otherwise authorized.
- Must maintain direct voice communication with the UAS pilot.

(h) Pilots operating as a formation flight will immediately notify ATC if they are using a nonstandard formation.

(i) Operations will not be conducted in instrument meteorological conditions (IMC).

(j) Operations will be thoroughly planned and briefed.

(k) During a lost link situation, the pilot must be notified immediately along with ATC. The chase pilot will report to ATC that the UA is performing lost link procedures as planned or if deviations are occurring.

(l) Pilot will ensure safe separation with the UA, and immediately notify ATC and the UA PIC during loss of visual contact with the UA by both the chase pilot and observer, when such contact cannot be promptly reestablished. The UA PIC will either execute lost link procedures to facilitate a rejoin, recover the UA, or terminate the flight as appropriate.

D. Notice to Air Missions (NOTAM).

1. A Distant (D) NOTAM must be issued, not less than 24-hours but not more than 72-hours, in advance of conducting routine UAS operations, unless operations are contained within Class A airspace, active restricted areas, or warning areas that are designated on the appropriate aeronautical chart or airport directory. This requirement may be accomplished:

a. Through the operator's local base operations or (D) NOTAM issuing authority; or

b. By contacting Fairbanks Flight Service Station (FSS) at 907-474-0137 or 866-248-6516. The issuing agency will require:

(1) Name and contact information of the pilot filing the (D) NOTAM request;

(2) COA number (2022-WSA-10342)

(3) Location, altitude, and operating area; and

(4) Time and nature of the activity.

2. The area of operation defined in the (D) NOTAM must only be for the actual area to be flown for each day defined by a point and the minimum radius required to conduct the operation.
3. Operator must cancel (D) NOTAMs when UAS operations are completed or will not be conducted.
4. For first responders only. Due to the immediacy of some emergency management operations, the (D) NOTAM notification requirement may be issued as soon as practicable before flight. If the issuance of a (D) NOTAM may endanger the safety of persons on the ground it may be excluded. If the (D) NOTAM is not issued, the proponent must be prepared to provide justification to the FAA upon request.

E. Reporting Requirements.

1. Documentation of all operations associated with UAS activities is required regardless of the airspace in which the UAS operates.
2. The proponent must submit the number of flights on a monthly basis through the COA application processing system (CAPS).

F. Special Use Airspace.

1. Coordination and de-confliction between Military Training Routes (MTR) and Special Use Airspace (SUA) is the operator's responsibility. When identifying an operational area, the operator must evaluate whether an MTR or SUA will be affected. In the event the UAS operational area overlaps an MTR or SUA, the operator will contact the scheduling agency in advance and as soon as practicable to coordinate and de-conflict. Approval from the scheduling agency is required for regulatory SUA, but not for MTRs and non-regulatory SUA. If there is no response to coordination efforts, the operator must exercise extreme caution and remain vigilant of all MTRs and/or non-regulatory SUAs.
2. Scheduling agencies for MTRs are listed in the Area Planning AP/1B, *Military Planning Routes, North and South America*. If unable to gain access to the AP/1B, contact the FAA with the instrument routes/visual routes affected at the following email addressing: 9-AJV-115-UASOrganization@faa.gov. The FAA will provide the scheduling agency information. Scheduling agencies for SUAs are listed in the FAA Order JO 7400.10, *Special Use Airspace*.

G. Air Traffic Control Requirements.

1. Coordination Requirements:
   a. Proponent filing a (D) NOTAM prior to commencing UAS operations will serve as sufficient notification to ZAN about operations conducted under this authorization. Cancellation of the NOTAM will serve as notification to ZAN of completion of flight in accordance with this provision.

b. Proponent must coordinate with Fairbanks ATCT at 907-474-0050.

(1) Coordination will be in accordance with procedures outlined in the Letter of Agreement between Fairbanks ATCT and University of Alaska Fairbanks (as amended/ superseded), where different, the procedures in this COA have priority.

(2) Coordination will include at a minimum, planned launch and recovery times, route of flight and NOTAM information.

c. Proponent will contact Fairbanks FSS at 907-474-0137 or 866-248-6516 prior to commencing UAS operations and coordinate flight details, including NOTAM and COA number.

d. Operations within Fairbanks Class D Airspace:

(1) UAS operations must be conducted per the Letter of Agreement between Fairbanks ATCT and University of Alaska Fairbanks as (amended/ superseded). Where different, the procedures in this COA have priority.

(2) UAS operations allowed only with clearance from Fairbanks ATCT.

e. UAS operating route intersects the Yukon MOA. The Proponent must notify Special Use Airspace Information Service (SUAIS) at 800-758-8723 or 907-372-6913 and provide operational details 24 hours prior to the start of operations.

2. Communication Requirements: PIC must be accessible, via phone number provided in NOTAM, or during initial coordination, for direct real-time communication and coordination purposes for the duration of UAS operations.

3. Flight Planning Requirements: It is the operator's responsibility for obtaining authorization from the appropriate authority for any operations that that may result in launching and/or landing from lands or waters administered by a Federal, State or Public agency (e.g., National Park, State Park, Wilderness Area, and Wildlife Refuge, etc.).

4. Procedural Requirements:

a. ATC may delay, limit, prohibit, or terminate UAS operations when the safety of manned aircraft operations are a concern.

b. UAS operations must remain clear of airport traffic patterns and not cross over any runway or taxiway unless otherwise coordinated.

H. Lost Link/Emergency/Contingency Procedures.

1. Lost Link Procedures: ATC does not need to be notified provided the PIC complies with the following provisions:

a. If a Lost Link occurs within Fairbanks Class D airspace, the UAS pilot will immediately notify Fairbanks ATCT on frequency 118.3 MHz, state pilot intentions, and comply with procedures within the Letter of Agreement between Fairbanks ATCT and University of Alaska Fairbanks as amended/ superseded.

b. If Lost Link occurs in Anchorage ARTCC airspace, the UAS pilot will immediately notify Anchorage ARTCC on assigned frequency and/or via phone at 907-269-1103, state pilot intentions, and provide the following information:

(1) The UAS's current, or last known, location in Latitude / Longitude coordinates or Fix/Radial/Distance (FRD).

(2) The programmed Lost Link Point (LLP), in coordinates or FRD, and the programmed route to the LLP, i.e. "direct" or "via".

(3) The UAS's current, or last known, altitude and the programmed Altitude for flight to the LPP.

(4) The pilot's intentions at the LLP, i.e., orbit (including orbit altitude if different)or flight termination.

(5) The identity, location, altitude of the chase plane.

c. The UAS lost link must be programmed to ensure that lost link flight does not fly over persons and the landing location is within the view of the PIC.

d. Lost link programmed procedures must avoid unexpected turn-around and/or altitude changes and will provide sufficient time to communicate and coordinate with ATC.

e. Lost link orbit points must not coincide with the centerline of Federal Victor or Colored airways or T routes.

2. Loss of Sight: If visual contact with the UAS is lost and cannot be regained, the lost link procedure must be executed.

3. Loss of Communication: The PIC will execute the lost link procedure in the event communications with the Chase plane or Visual Observer(s) are lost.

4. Emergency/Fly-Away Procedures: In the event of an emergency/fly-away toward an area or airport where the PIC has determined the UAS may create a hazard to aviation, the PIC must immediately the appropriate facility.

   a. Facility Contact:

      (1) ZAN - 907-269-1103

      (2) FAI - 907-474-0452

      (3) FBK - 907-353-9206

   b. The PIC must provide the following information:

      (1) Approximate location.

      (2) Direction of flight.

      (3) Last known altitude.

      (4) Maximum remaining flight time.

AUTHORIZATION

This COA does not, in itself, waive any Title 14 CFR not specifically stated, nor any state law or local ordinance. Should the proposed operation conflict with any state law or local ordinance, or require permission of local authorities or property owners, it is the responsibility of the proponent to resolve the matter. This COA does not authorize flight within Temporary Flight Restrictions, Special Flight Rule Areas, regulatory SUA, or the Washington DC Federal Restricted Zone without pre-approval. The Proponent is hereby authorized to operate the small UAS in the NAS within the areas defined in the Operations Authorized section of the cover page.

Attachment 1

Operations Area
Class D, E, and G Airspace
At or below 10,000 feet MSL

Attachment 2

Operations Area
Class D, E, and G Airspace
At or below 10,000 feet MSL

65°11'8"N	147°28'10"W
64°55'50"N	147°51'31"W
64°55'41"N	147°55'3"W
64°55'7"N	147°58'46"W
64°54'21"N	148°1'28"W
64°52'54"N	148°4'43"W
64°51'6"N	148°7'14"W
64°49'37"N	148°7'54"W
64°47'35"N	148°7'33"W
64°45'51"N	148°5'51"W
64°44'8"N	148°2'45"W
64°42'54"N	147°59'15"W
64°42'10"N	147°55'3"W

64°42'8"N	147°49'27"W
64°42'52"N	147°44'43"W
64°43'57"N	147°41'8"W
64°51'28"N	147°44'30"W
64°58'54"N	147°18'53"W
65°45'37"N	143°55'40"W
65°47'7"N	143°52'55"W
65°48'59"N	143°51'13"W
65°51'34"N	143°51'5"W
65°53'34"N	143°53'7"W
65°54'59"N	143°56'50"W
65°55'39"N	144°2'41"W
65°55'46"N	144°10'56"W

16 APPENDIX E - MEMORANDUM OF AGREEMENT - UNMANNED AIRCRAFT SYSTEMS (UAS) OPERATIONS AT FAIRBANKS INTERNATIONAL AIRPORT (FAI)

University of Alaska Fairbanks/Alaska Center for Unmanned Aircraft Systems Integration and the Fairbanks International Airport

MEMORANDUM OF AGREEMENT
Unmanned Aircraft Systems (UAS) Operations at Fairbanks International Airport (FAI)

EFFECTIVE September 1, 2019

1. Purpose: To establish common policies and permissions for the operation of UAS at Fairbanks International Airport (FAI) by the University of Alaska Fairbanks/ Alaska Center for Unmanned Aircraft Systems Integration (UAF/ACUASI). These policies will establish baseline operations to safely integrate UAS operations into the airfield like any other manned aircraft and communicate to applicable groups how UAS airfield operations will occur.

2. Scope: The policies herein apply to the University of Alaska Fairbanks's Alaska Center for Unmanned Aircraft Systems Integration UAS Flight Operations and the Fairbanks International Airport.

3. Responsibilities: Parties of this Memorandum of Agreement (MOA) must ensure they comply with the provisions applicable to them as detailed herein.

4. Date and Term: The MOU will become effective on September 1, 2019, and will remain in effective for five (5) years, ending on August 31, 2026. This agreement may be amended or canceled in writing by either party with thirty (30) days' notice.

5. Policies:

a. Introduction of UAS to FAI airfield operations:

(1) At least 2 weeks prior to first operational flight and as UAS fleet changes occur, UAF/ACUASI shall brief FAI Operations on the following subjects: flight envelope, UAS's capabilities/limitations, runway operations, approach and landing, safety or security concerns, and any operations of UAS on airport property that would be different from that of a manned aircraft.

(2) Prior to first flight and as fleet changes occur, UAF/ACUASI shall brief FAI aircraft rescue and firefighting (ARFF) personnel on aircraft and ground control station hazards. This should include coordinating of emergency response procedures that FAI will implement with the Air Traffic Control Tower (ATCT).

(3) A current Certificate of Authorization (COA) and this MOA must be on file with the Air Traffic Controller (ATC) and FAI Operations prior to operating within the Class D airspace.

1

(4) UAF/ACUASI shall notify FAI Operations at least 24 hours prior to any intended flight operations with the following information: Type of UAS flying, intended time of flight, and any known or anticipated impact to airport operations.

(5) FAI must give approval for each UAS prior to initial operation. When a previously approved UAS capabilities change, FAI must give approval to each UAS prior to restarted airfield operations. These approvals will be provided to UAF/ACUASI in writing from the Airport Manager or designee. UAF/ACUASI will maintain a list of approved UAS in their inventory and notify FAI as that inventory changes.

b. Communications: Primary ground and flight communications are with published VHF frequencies and will follow standard aircraft communications protocol.

UAF/Alaska Center for UAS Integration		**Fairbanks International Airport**	
Position	Phone#	Position	Phone#
Director, ACUASI	907-474-6905	Tower Chief	907-474-0050
Director of Operations	907-455-2023	Tower Cab	907-474-0452
Safety Manager	907-455-2014	Fire Chief	907-474-2575
Chief Pilot	907-455-2036	Airport Communications Center	907-474-2530
ACUASI Office	907-455-2016	Airport Operations	907-451-2300
		Airport Ops Chief	907-474-2550

(1) Media: Both parties agree to request approval from the other any time press or media coverage will be taking place regarding UAS equipment or operations at FAI. Such requests will be 24 hrs. in advance.

c. Ground Operations:

(1) UAF/ACUASI UAS ground operations must be consistent and equivalent to manned aircraft ground operations occurring at FAI.

(2) The East Ramp airfield facilities will be the regular and primary operations area for all UAS operations. This includes Taxiways Delta and Charlie, and runway 2R/20L, and immediately adjacent taxiways. Operations on 2L/20R may only occur in a declared emergency situation as directed by ATCT.

(3) When on controlled surface areas, UAS Remote Pilot in Command (RPIC) will maintain two-way radio contact with ATCT.

(4) Placement of ground control or other devices intended to be installed on FAI property requires execution of a permit from FAI Leasing.

(5) UAF/ACUASI personnel and operations will comply with all FAI operational orders, direction from FAI Operations/Police/Fire Officers, and FAA regulations.

d. Safety:

(1) If a ground operation or flight event occurs that has or may cause an unsafe situation (as determined by either FAI, UAF/ACUASI, or ATCT), UAS operations must halt until parties of this agreement convene to discuss the situation and implement solutions to ensure airport, aircraft, and UAS safety. Operations may not restart until both FAI and UAF/ACUASI are satisfied with the mitigation.

(2) UAF/ACUASI is expected to be a participating member of FAI's Runway Safety Action Team (RSAT), which meets at least annually to review surface incidents and to recommend changes, as needed, to improve safety.

(3) UAS Operations must follow all standard protocol for flight patterns and coordination with the ATCT.

(4)

6. Compliance with Law: The parties specifically intend to comply with all applicable laws, rules and regulations as they may be amended from time to time. If any part of this Agreement is determined to violate federal, state, or local laws, rules, or regulations, the parties agree to negotiate in good faith revisions to any such provisions. If the parties fail to agree within a reasonable time to revisions required to bring the entire Agreement into compliance, either party may terminate this Agreement upon thirty (30) days prior written notice to the other party.

This agreement will be reviewed by the parties after 10 flight operations to determine any needed change of modification.

6. Funding and costs: The parties shall each be solely responsible for any and all costs associated with their responsibilities under this MOA.

7. Indemnity: UAF/ACUASI shall indemnify, defend, and hold harmless FAI from and against any and all liabilities, claims, losses, lawsuits, judgments, and/or expenses, including attorney fees, arising either directly or indirectly from any act or failure to act by UAF/ACUASI or any of its officers or employees, which may occur during or which may arise out of the performance of this Agreement.

Signatures:
The parties indicate agreement with this Memorandum of Agreement by their signatures below.

Digitally signed by Rosemary Madnick
DN: cn=Rosemary Madnick, o=University of Alaska Fairbanks, ou=Office of Grants & Contracts Administration, email=rmadnick@alaska.edu, c=US
Date: 2019.09.19 12:51:15 -08'00'
Adobe Acrobat version: 2017.011.30148

Angie Spear
Airport Manager
Fairbanks International Airport

Rosemary Madnick
Executive Director
Office of Grants & Contracts Administration
University of Alaska Fairbanks

17 APPENDIX F - LETTER OF AGREEMENT BETWEEN FAIRBANKS AIRPORT TRAFFIC CONTROL TOWER AND THE ALASKA CENTER FOR UNMANNED AIRCRAFT SYSTEMS INTEGRATION

Fairbanks Airport Traffic Control Tower and the Alaska Center for Unmanned Aircraft Systems Integration

LETTER OF AGREEMENT

EFFECTIVE: May 20, 2022

SUBJECT: Unmanned Aircraft Systems (UAS) Operations within Fairbanks Airport Traffic Control Tower Class D Airspace

1. PURPOSE: To define responsibilities, procedures and coordination requirements for the operation of UAS within the Fairbanks (FAI) Class D Airspace.

2. CANCELLATION: This letter of agreement (LOA) may be canceled upon written notification by one or more of the signatories. This notification must be submitted a minimum of 30 days prior to the proposed cancellation date.

3. SCOPE: The procedures contained herein apply to Fairbanks Airport Traffic Control Tower (FAI ATCT) and Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) Flight Operations.

4. RESPONSIBILITY: The parties to this agreement must ensure applicable personnel are trained and certified and adhere to the guidance set forth in this LOA.

5. PROCEDURES:

a. Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) Flight Operations must:

(1) Have a current Certificate of Authorization or Waiver (COA) and signed LOA on file with FAI ATCT prior to operating within the FAI Class D Airspace.

(2) Operate in accordance with (IAW) Visual Flight Rules (VFR) at all times.

(3) Not operate within the FAI Class D Airspace if the official airfield weather is reported as less than 1,000 foot ceiling and/or visibility less than three statute miles.

(4) Conduct UAS operations during light density traffic time-periods as determined by FAI ATCT. The FAI ATCT at their discretion may temporarily terminate or suspend daily UAS operations at any time for any reason.

(5) Provide FAI ATCT via telephone at (907) 474-0452 with the scheduled launch and recovery times, route of flight or intentions, remote pilot telephone number, and notice to air missions (NOTAM) information for the UAS activity at least one hour prior to the start of flight operation.

(6) Comply with all Air Traffic Control (ATC) instructions.

(7) Be able to see and avoid then give way to all manned aircraft at all times.

Fairbanks Airport Traffic Control Tower and the Alaska Center for Unmanned Aircraft Systems Integration

NOTE: Manned aircraft have priority over unmanned aircraft at all times.

(8) Maintain direct two-way radio communications with the FAI ATCT during the conduct of all flight operations on frequency 118.3 MHz and/or the FAI Approach Control on frequency 125.35 MHz.

(9) Have an operating transponder and receive a discreet transponder beacon code from FAI ATCT prior to departing.

(10) Operate at 1,500' mean sea level (MSL) when doing local traffic pattern work within the Class D Airspace.

(11) In the event of lost command and/or control communications, advise FAI ATCT immediately via radio or telephone at (907) 474-0452. The PIC will follow all ATC instructions including proceeding to the lost link point described in # (14) below.

(12) Provide visual observers and chase plane aircraft who must maintain visual contact with the UAS at all times during flights operations within the FAI Class D Airspace.

(13) Advise FAI ATCT when visual contact is lost during flight in Class D Airspace:

(a) Inform FAI ATCT of the last known position, direction of flight, and altitude of the UAS.

(b) If visual contact is not re-acquired within 1 minute of losing sight of the UAS, proceed to the lost link point.

(c) Advise FAI ATCT when visual contact is reestablished.

(14) In the event of a lost link while operating within the FAI Class D Airspace, the UAS will proceed to 64° 45' 32"N / 147° 47' 41"W and hold at 3,500' MSL (approximately 3 nautical miles (NM) south of Metro Field Airport (MTF) / 3.75NM southeast of Fairbanks International Airport (PAFA) on a 139 degree bearing from the Airport Reference Point. The UAS will be preprogramed to remain within 1NM of the hold point and remain there until link is reestablished or a safe flight termination procedure is coordinated with ATC.

(15) In the event of a UAS emergency, the PIC must contact FAI ATCT immediately and advise them of the situation and intentions if known.

(16) The PIC must advise FAI ATCT when all UAS operations are completed.

b. FAI ATCT must:

(1) Provide local air traffic advisory services only IAW FAA Order 7110.65, Air Traffic Control, local operating procedures, and the applicable UAS COA within the Class D Airspace and approach control airspace on a workload permitting basis.

(2) Assign a transponder beacon code and appropriate operating instructions prior to departure.

(3) Assist the chase plane with join-up to the UAS if requested.

(4) If deemed necessary, record on the automated terminal information services (ATIS) that UAS activity is being conducted within the FAI Class D Airspace.

c. UAS operations not authorized by the FAI ATCT:

(1) Opposite direction operations

(2) Land and hold short operations

(3) Line up and wait

(4) Special visual flight rules (VFR)

d. Safety: If a situation arises during a UAS operation that caused or may cause an unsafe situation in the National Airspace System (NAS) or FAI Class D Airspace, all future UAS operations must be temporarily suspended. The Parties of this agreement will convene and resolve the issue prior to resuming additional UAS operations.

6. ATTACHMENT: FAI Class D Airspace

TIMOTHY R LONG Digitally signed by TIMOTHY R LONG Date: 2022.05.05 13:59:07 -08'00'

Timothy Long
Air Traffic Manager
Fairbanks Airport Traffic Control Tower

DocuSigned by: Catherine F. Cahill

Dr. Catherine F. Cahill
Director
ACUASI

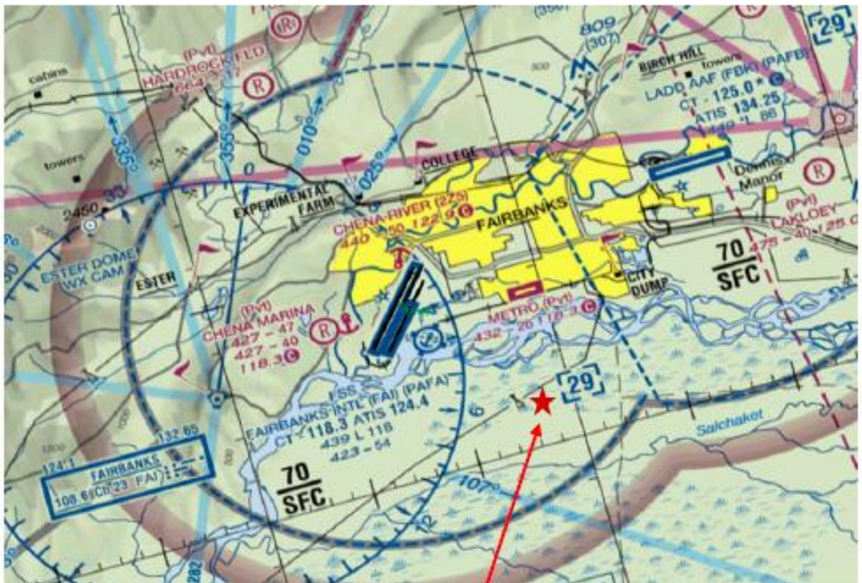
DocuSigned by: Nettie La Belle-Hamer

Dr. Nettie La Belle-Hamer
Vice Chancellor for Research
University of Alaska Fairbanks

DS RPM

Fairbanks Airport Traffic Control Tower and the Alaska Center for Unmanned Aircraft Systems Integration

Attachment- FAI Class D Airspace
COA area approved for the UAS operation
& approximate Lost Link Point



Lost Link Point

64 45 32N / 147 47 41W

@ 3,500MSL

18 APPENDIX G - COA - NENANA MUNICIPAL AIRPORT

FAA FORM 7711-1 UAS COA
2021-WSA-9404 COA

Page 1 of 8

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

CERTIFICATE OF WAIVER OR AUTHORIZATION

ISSUED TO

University of Alaska Fairbanks, Geophysical Institute — Part 91

ADDRESS

Alaska Center for UAS Integration
2160 Koyukuk Drive
Fairbanks, AK 99775

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED

Operation of the Sentry HP, Perimeter, SeaHunter and various small Unmanned Aircraft Systems (UAS) in Class E and G airspace, at or below 5,000 feet Above Ground Level (AGL), over Nenana, Alaska, under jurisdiction of Fairbanks Terminal Radar Approach Control (FAI) and Anchorage Air Route Traffic Control Center (ZAN). See Special Provisions.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE

N/A

STANDARD PROVISIONS

1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein.
4. This certificate is nontransferable.

Note-This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.

SPECIAL PROVISIONS

Special Provisions A thru H, inclusive, are set forth on the reverse side hereof.

This certificate is effective from October 12, 2021 to October 11, 2023 and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.

BY DIRECTION OF THE ADMINISTRATOR

ADAM A VETTER — Digitally signed by ADAM A VETTER Date: 2021.10.12 10:07:39 -07'00'

FAA Western Service Area (Region)	Adam Vetter (Signature)
October 12, 2021 (Date)	Tactical Operations Manager (Title)

FAA Form 7711-1 (7-74)

Version Date: May 2019

Purpose: To prescribe UAS operating requirements in the National Airspace System (NAS) for the purpose of Public Aircraft Operations. The holder of this COA will be referred herein as the "Proponent."

Public Aircraft

1. Public aircraft operation are determined by statutes, 49 USC § 40102(a)(41) and § 40125.
2. All public aircraft flights conducted under a COA must comply with the terms of the statute.
3. All flights must be conducted per the declarations submitted in the application, and as specified in the following Special Provisions.
4. This COA provides an alternate means of complying with 14 CFR § 91.113(b) for unmanned aircraft operations.
5. All operations will be conducted in compliance with Title 14 CFR § 91 and the conditions of the authorization issued herein. If the operator cannot adhere to any of these requirements, a separate FAA Form 7711-2 waiver application may be required.

SPECIAL PROVISIONS

A. General.

1. All personnel connected with the UAS operation must read and comply with the contents of this authorization and its provisions.
2. A copy of the COA including the special limitations must be immediately available to all operational personnel at each operating location whenever UAS operations are conducted.
3. This authorization may be canceled at any time by the Administrator, the person authorized to grant the authorization, or the representative designated to monitor a specific operation. As a general rule, this authorization may be canceled when it is no longer required, there is an abuse of its provisions, or when unforeseen safety factors develop. Failure to comply with the authorization is cause for cancellation. The proponent will receive a written notice of cancellation.
4. During the time this COA is approved and active, a site safety evaluation/visit may be accomplished to ensure COA compliance, assess any adverse impact on ATC or airspace, and ensure this COA is not burdensome or ineffective. Deviations, accidents/incidents/mishaps, complaints, etc., will prompt a COA review or site visit to address the issue. Refusal to allow a site safety evaluation/visit may result in cancellation of the COA. Note: This section does not pertain to agencies that have other existing agreements in place with the FAA.
5. Radiofrequency spectrum authorization is independent of the COA process and requires the proponent to obtain Federal Communications Commission (FCC) equipment certification (47 CFR Part 2, Subpart J and 47 CFR Part 87, Subpart D) and frequency licenses (47 CFR Part 87) in the Aeronautical Radionavigation, Aeronautical Mobile (Route), or Aeronautical Mobile Services, as appropriate, for the control link, ATC radios, transponders, detect and avoid systems, and navigation systems used to support this COA. For systems operating exclusively below 400 feet, and within visual line of

sight, the control link equipment may be licensed under 47 CFR Part 15 (Radio Frequency Devices). Equipment licensed under 47 CFR Part 5 (Experimental) does not provide the protection necessary for NAS operations.

B. Operations.

1. Unless otherwise authorized as a special provision, a maximum of one unmanned aircraft will be controlled:
   a. From a single control station; and
   b. By one pilot at a time.
2. When necessary, transit of airways and routes must be conducted as expeditiously as possible. The unmanned aircraft should not plan to loiter on Victor airways, jet routes, Q and T routes, IR routes, or VR routes.
3. For flights operating on an IFR clearance, the PIC must ensure positional information in reference to established National Airspace System (NAS) fixes, NAVAIDs, and/or waypoints are provided to ATC. The use of latitude/longitude positions is not authorized, except oceanic flight operations.
4. Unless installed as part of a Detect and Avoid (DAA) system, the use of a Traffic Collision Avoidance System (TCAS) in Traffic Advisory (TA) or Traffic Advisory/Resolution Advisory (TA/RA) modes while operating an unmanned aircraft is prohibited.

C. Safety of Flight.

1. The operator or delegated representative is responsible for halting or canceling activity in the COA area if, at any time, the safety of persons or property on the ground or in the air is in jeopardy, or if there is a failure to comply with the terms or conditions of this authorization.
   a. Any crew member responsible for performing see-and-avoid requirements for the UA must have and maintain instantaneous communication with the PIC.
   b. Visual observers must be used at all times except in Class A airspace, active restricted areas, and warning areas designated for aviation activities or as authorized in the Special Provisions. Observers may either be ground-based or airborne in a chase plane.
      (1) Visual Observers:
         (a) Must be able to communicate clearly to the pilot any instructions required to remain clear of conflicting traffic, using standard phraseology as listed in the Aeronautical Information Manual when practical.
         (b) The PIC is responsible to ensure visual observers are able to see the aircraft and the surrounding airspace throughout the entire flight, and
         (c) The PIC is responsible to ensure visual observers are able to provide the PIC with the UA's flight path, and proximity to all aviation activities and other hazards (e.g., terrain, weather, structures) sufficiently to exercise effective control of the UA to:

- Comply with 14 CFR § 91.111, §91.113, and § 91.115;
- Prevent the UA from creating a collision hazard; and
- Comply with all conditions of this COA.

(2) Chase Aircraft:

(a) If the chase aircraft is operating more than 1 mile laterally or longitudinally and/or more than 100 feet vertically of the unmanned aircraft, the chase aircraft PIC will advise the controlling ATC facility.

(b) Must remain at a safe distance from the UA to ensure collision avoidance if a malfunction occurs.

(c) Must remain close enough to the UA to provide visual detection of any conflicting aircraft and advise the PIC of the situation.

(d) Must remain within radio control range of the UA to maintain appropriate signal coverage for flight control or activation of the Flight Termination System, for all operations when the UA is being flown by a pilot in the chase aircraft.

(e) May be required to have communication with appropriate ATC facilities based on the operator's application or mission profile.

(f) Must maintain five (5) statute miles in-flight visibility restrictions.

(g) Pilot/observer:

- Will not concurrently perform either observer or UAS pilot duties along with chase pilot duties unless otherwise authorized.
- Must maintain direct voice communication with the UAS pilot.

(h) Pilots operating as a formation flight will immediately notify ATC if they are using a nonstandard formation.

(i) Operations will not be conducted in instrument meteorological conditions (IMC).

(j) Operations will be thoroughly planned and briefed.

(k) During a lost link situation, the pilot must be notified immediately along with ATC. The chase pilot will report to ATC that the UA is performing lost link procedures as planned or if deviations are occurring.

(l) Pilot will ensure safe separation with the UA, and immediately notify ATC and the UA PIC during loss of visual contact with the UA by both the chase pilot and observer, when such contact cannot be promptly reestablished. The UA PIC will either execute lost link procedures to facilitate a rejoin, recover the UA, or terminate the flight as appropriate.

D. Notice to Airmen (NOTAM).

1. A Distant (D) NOTAM must be issued prior to conducting UAS operations not more than 72 hours in advance, but not less than 24 hours for UAS operations prior to the operation

for routine operations unless operations are contained within Class A airspace, active restricted or warning areas that are designated on the appropriate aeronautical chart or airport directory. This requirement may be accomplished:

a. Through the operator's local base operations or (D) NOTAM issuing authority; or

b. By contacting the Fairbanks Flight Service Station at 907-474-0788. The issuing agency will require:

(1) Name and contact information of the pilot filing the NOTAM request.

(2) Location, altitude, or operating area.

(3) Time and nature of the activity.

2. The area of operation defined in the (D) NOTAM must only be for the actual area to be flown for each day defined by a point and the minimum radius required to conduct the operation.

3. Operator must cancel (D) NOTAMs when UAS operations are completed or will not be conducted.

4. For first responders only. Due to the immediacy of some emergency management operations, the (D) NOTAM notification requirement may be issued as soon as practical before flight and if the issuance of a (D) NOTAM may endanger the safety of persons on the ground, it may be excluded. If the (D) NOTAM is not issued, the proponent must be prepared to provide justification to the FAA upon request.

E. Reporting Requirements.

1. Documentation of all operations associated with UAS activities is required regardless of the airspace in which the UAS operates.

2. The proponent must submit the number of flights on a monthly basis through the COA Application Processing System (CAPS).

F. Special Use Airspace.

1. Coordination and de-confliction between Military Training Routes (MTR) and Special Use Airspace (SUA) is the operator's responsibility. When identifying an operational area the operator must evaluate whether an MTR or SUA will be affected. In the event the UAS operational area overlaps an MTR or SUA, the operator will contact the scheduling agency as soon as practicable in advance to coordinate and de-conflict. Approval from the scheduling agency is required for regulatory SUA, but not for MTRs and non-regulatory SUA. If no response to coordination efforts, the operator must exercise extreme caution and remain vigilant of all MTRs and/or non-regulatory SUAs.

2. Scheduling agencies for MTRs are listed in the Area Planning AP/1B Military Planning Routes North and South America. If unable to gain access to AP/1B contact the FAA at email address mail to: 9-AJV-115-UASOrganization@faa.gov with the IR/VR routes affected and the FAA will provide the scheduling agency information. Scheduling agencies for SUAs are listed in the FAA JO 7400.10.

G. Air Traffic Control (ATC) Requirements.

1. Coordination Requirements:

   a. Proponent must contact FAI at 907-474-0452 one (1) hour prior to commencing operation(s) and provide pertinent flight details, including (D) NOTAM number.

   b. Proponent must contact FAI within 15 minutes of terminating operation(s).

2. Communication Requirements: PIC must be accessible, via phone number provided in NOTAM, or during initial coordination, for direct real-time communication and coordination purposes for the duration of UAS operation(s).

3. Procedural Requirements:

   a. ATC may delay, limit, prohibit, or terminate UAS operations when the safety of manned aircraft operations are a concern.

   b. UAS operations must remain clear of airport traffic patterns and not cross over any runway or taxiway unless otherwise coordinated.

   c. Daisy chaining of visual observers:

      (1) Visual observers are briefed on the aircraft flight path and are prepositioned before takeoff. The locations of the observers are marked on the GCS moving map display.

      (2) Visual observers have immediate communications with the PIC using handheld transceivers. All radio communications with all observers is verified before takeoff. During flight, if radio communications are lost the aircraft is tasked to reverse course and head back for landing.

      (3) Visual observers perform positive hand-off of responsibilities between each other. Observer 1 transmits when the UA is in sight, passing overhead, headed for Observer 2 and nearing the limits of observation by Observer 1. Observer 2 transmits when the UA is in sight, passing overhead, headed for the next observer, and nearing the limits of observation by Observer 2. The process is repeated until the UA has completed its flight plan and has returned to the launch point.

      (4) If Observer 2 cannot acquire the U from Observer 1, the GCS operator transmits the location of the UA relative to Observer 2 (i.e., 0.5 nm north of your position). If Observer 2 still cannot locate the UA, the aircraft is tasked to reverse course and head back to Observer 1. If Observer 1 cannot acquire the UA, the aircraft is tasked to continue on the reversed course and head back for landing.

      (5) If there is any in-flight emergency, the UA is tasked to reverse course and return for landing.

H. Lost Link/Emergency/Contingency Procedures.

1. Lost Link Procedures. In the event of a lost link, the UAS pilot will immediately comply with the following provisions:

   a. The UA must be programmed to ensure lost link flight does not fly over persons and the landing location is within the view of the PIC.

b. Lost link procedures must be programmed to remain within the operations area and approved altitude, avoid unexpected turn-around and/or altitude changes, and will provide sufficient time to communicate with ATC if necessary.

2. Loss of Sight. If a VO loses sight of the UA, the PIC must be notified immediately. If the UA is visually reacquired promptly, the mission may continue. If not, the PIC must immediately terminate the operation and the UA must return to land.

3. Lost Communications. If voice communication between the PIC and the visual observer(s) is lost, the PIC must recover the UA using the lost link procedure. If communication is reestablished, the PIC can resume the flight if deemed safe to do so.

4. Emergency/Fly-Away Procedures. In the event of an emergency/fly-away toward an area or airport where the PIC determines the UA may create a hazard to aviation, the PIC must immediately notify the appropriate ATC facility.

   a. Facility Contact:

      (1) FAI – 907-474-0452.

      (2) ZAN – 907-269-1103.

   b. The PIC should provide the following information:

      (1) Approximate UA location.

      (2) Direction of flight.

      (3) Last known altitude.

      (4) Maximum remaining flight time.

AUTHORIZATION

This Certificate of Waiver or Authorization does not, in itself, waive any Title 14 Code of Federal Regulations not specifically stated, nor any state law or local ordinance. Should the proposed operation conflict with any state law or local ordinance, or require permission of local authorities or property owners, it is the responsibility of the proponent to resolve the matter. This COA does not authorize flight within Temporary Flight Restrictions, Special Flight Rule Areas, regulatory Special Use Airspace, or the Washington DC Federal Restricted Zone (FRZ) without pre-approval. The proponent is hereby authorized to operate the Unmanned Aircraft System in the NAS within the areas defined in the Operations Authorized section of the cover page.

Attachment 1

Operating Area (outlined in green)
Class E and G Airspace
8 nautical mile radius of 64°32'50"N 149°4'29"W
At or below 5,000 feet AGL

Version Date: May 2019