# Final Report

# ASSURE A52: Phase II - Preparation for Disaster Preparedness and Response using UAS in the NAS with Coordination Across First Responders

October 1, 2024

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## NOTICE

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**16. Abstract**
The Alliance for System Safety of UAS through Research Excellence (ASSURE) team was tasked by the Federal Aviation Administration (FAA) with research related the safe integration of UAS into the disaster preparedness and response areas. This research will look at how UAS can aid in disaster preparedness and response to different natural and human-made disasters. It will focus on procedures to coordinate with the Department of Interior (DOI), the Department Of Homeland Security (DHS) including the Federal Emergency Management Agency (FEMA) and other federal, local and state governments to ensure proper coordination during those emergencies.

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|---|---|
| **AAR** | After Action Review |
| ACUASI | Alaska Center For UAS Integration |
| ADS-B | Automatic Dependent Surveillance–Broadcast |
| AGL | Above Ground Level |
| ALDOT | Alabama Department Of Transportation |
| AOA | Airport Operations Area |
| ARTCC | Air Route Traffic Control Center |
| ASSURE | Alliance For System Safety Of UAS Through Research Excellence |
| ATC | Air Traffic Control |
| AT&T | American Telephone And Telegraph |
| AUVSI | Association of Uncrewed Aircraft System International |
| BTV | Burlington International Airport |
| BVLOS | Beyond Visual Line Of Sight |
| C-UAS | Counter Unmanned Aircraft System |
| C2 | Command And Control |
| CAP | Civil Air Patrol |
| COA | Certificate Of Waiver Or Authorization |
| CONOPs | Concepts Of Operations |
| COVID 19 | Coronavirus Disease 2019 |
| CPU | Central Processing Unit |
| CTAF | Common Traffic Advisory Frequency |

| | |
|---|---|
| CURSE | Catastrophic UAS Remote Sensing Exercise |
| DAA | Detect And Avoid |
| DHS | Department Of Homeland Security |
| DLI | Divert Land Immediately |
| DOI | Department Of The Interior |
| EDT | Eastern Daylight Time |
| EO/IR | Electro-Optical/Infrared |
| EOC | Emergency Operations Center |
| FAA | Federal Aviation Administration |
| FEMA | Federal Emergency Management Agency |
| GDA | Geospatial Damage Assessment |
| **GIS** | Geographic Information System |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GPU | Graphics Processing Unit |
| HSV | Huntsville International Airport |
| ICS | Incident Command System |
| IFR | Instrument Flight Rules |
| IMT | Incident Management Team |
| JPG | Joint Photographic Group |
| KML | Keyhole Markup Language |
| KMZ | Zipped Keyhole Markup Language |

| | |
|---|---|
| KSU | Kansas State University |
| LAANC | Low Altitude Authorization And Notification Capability |
| LiDAR | Laser Imaging, Detection, And Ranging |
| lUAS | Large UAS |
| LZ | Landing Zone |
| METAR | Meteorological Aerodrome Report |
| ML | Machine Learning |
| MSU | Mississippi State University |
| NAS | National Airspace System |
| NASA | National Aeronautics And Space Administration |
| NFZ | No Fly Zone |
| NM | Nautical Mile |
| NMSU | New Mexico State University |
| OOP | Operations Over People |
| ORA | Operational Risk Analysis |
| PIC | Pilot In Command |
| PIREP | Pilot Report |
| PPK | Post-Processing Kinematic |
| RAM | Random Access Memory |
| RASPET | Raspet Flight Research Laboratory |
| RAW-format | Raw image file contains unprocessed or minimally processed data from the image sensor |
| RGB | Red, Green, Blue - Visual Range Imagery |

| | |
|---|---|
| RPIC | Remote Pilot In Command |
| RTB | Return To Base |
| RTK | Real-Time Kinematic |
| RTL | Return To Landing |
| SA | Situational Awareness |
| SAL | Spatial Analysis Laboratory |
| SAR | Search And Rescue |
| SARCOP | Search And Rescue Common Operating Platform |
| SCAT | Shoreline Cleanup And Assessment Technique |
| SEOC | State Emergency Operations Center |
| SfM | Structure from Motion |
| SGI | Special Government Interest |
| SOSC | System Operations Support Center |
| sUAS | Small UAS |
| TFR | Temporary Flight Restrictions |
| TIM | Technical Interchange Meeting |
| UAF | University Of Alaska Fairbanks |
| UAH | University Of Alabama In Huntsville |
| UAS | Unmanned Aircraft System |
| UAS-JTAC | UAS Joint Terminal Attack Controller |
| UNICOM | Universal Communications |
| USAR | Urban Search and Rescue |

| | |
|---|---|
| USGS | United States Geodetic Survey |
| UTM | UAS Traffic Management |
| UVM | University Of Vermont |
| VCGI | Vermont Center For Geographic Information |
| VLOS | Visual Line Of Sight |
| VNIR | Visible And Near Infrared |
| VO | Visual Observer |
| VT-TF1 | Vermont Task Force 1 |
| VTOL | Vertical Take Off And Landing |
| VTrans | Vermont Agency Of Transportation |
| YKHC | Yukon-Kuskokwim Health Corporation |

# EXECUTIVE SUMMARY

The ASSURE A52 Phase II project, initiated by the Federal Aviation Administration (FAA), was designed to evaluate the role of Unmanned Aircraft Systems (UAS) in disaster preparedness and response, focusing on how UAS can be integrated into the National Airspace System (NAS). The primary objective of this research was to enhance disaster response capabilities by identifying the strengths and limitations of UAS in various disaster scenarios and establishing best practices for their deployment in real-world emergencies. This phase built upon the "Beyond Part 107" document developed in Phase I to assist first responders in understanding UAS roles and limitations during disaster response.

The ASSURE A52 framework aimed to understand how UAS can reduce response times, improve agency coordination, and provide real-time data to support decision-making during disasters. The research covered a broad range of disaster types, including hurricanes, wildfires, pandemics, oil spills, and train derailments. Through this work, the project sought to address critical questions such as identifying best practices for UAS integration in disaster response, determining how operations can be standardized across various disaster types, and understanding the regulatory changes needed for rapid UAS deployment.

To address these questions, the ASSURE A52 team conducted 29 events, including mock demonstrations, workshops, and functional exercises across the US. These events tested UAS operations in realistic disaster settings, from hurricanes in Alabama to medical supply deliveries during pandemics in Alaska, and real-time flooding response in Vermont. The methodology involved detailed pre-event planning for safe UAS deployment, simulations in challenging environments, multi-agency coordination, and post-event analysis to gain insights into UAS performance and operational challenges.

The research produced significant findings. UAS have proven beneficial in disaster-related tasks such as oversight, search and rescue, imaging, mapping, and transporting critical goods like medical supplies. However, there is wide variation in the knowledge, expertise, and training regarding UAS use across local, state, and federal organizations. The project introduced the concept of Minimal Operational Proficiency Standards (MOPS), highlighting the need for training and accreditation processes to evaluate and credential UAS operators. As UAS use in disaster exercises and real-world events increases, their utility is expected to expand further. The project also underscored the importance of Functional Exercises, where operators interacted with real or simulated environments and incident command to assess risks and adapt to changing circumstances, delivering actionable data to save lives and expedite recovery.

Looking ahead, Phase III will further refine the regulatory structure to create emergency-specific guidelines that expedite UAS deployment. Additionally, the team will develop uniform standards for UAS operations to ensure consistent data collection and usage across agencies. Multi-agency collaboration between the FAA, FEMA, and NIST will be key to executing standardized training for first responders, UAS operators, and agency leaders to improve interoperability during disaster response efforts. Lastly, continued industry investment in UAS technology is critical to advancing capabilities such as battery life, payload capacity, and data transmission in disaster environments. This research represents a pivotal step toward building a national framework for UAS disaster response, ensuring that UAS technology is fully leveraged to save lives and mitigate damage in future disaster scenarios.

# 1 INTRODUCTION & BACKGROUND

This A52 project entitled "A11L.UAS.68: Disaster Preparedness and Emergency Response Phase II," was awarded as a follow-on to the A28 effort, within which the research was oriented toward the development of Concepts Of Operations (CONOPs) likely to be encountered and appropriate to various kinds of natural and man-made disasters. The A28 team evaluated dozens of historical disasters – hurricanes, tornadoes, floods, wind events, volcanoes, seismic events, earthquakes, landslides, avalanches, pandemics, oil spills, terrorism, and biohazards – examining each example for ways in which the use of UAS was effective and demonstrated positive value. Each historical event was also examined to determine possible lessons learned that related to drone usage in disaster response situations.

Another group within the A28 team examined certain past disasters, focusing on the interorganizational relationships of responders and established communication patterns. The team developed Use Case diagrams depicting the high-level interactions among the involved entities that occurred during the disaster. The entities were identified in these diagrams as actors, while the interactions were identified as use cases.

A third group of analysts examined various detailed use cases, again across a wide spectrum of imagined disasters, enumerating the many ways in which various kinds of UASs might be brought into disaster response service. This modeling included the kinds of aircrafts and sensors most appropriate for specific missions, the phase of the disaster within which they would be expected to participate, the hazards associated with their use, the type of flight (Certificate Of Waiver Or Authorization (COA)/Part 107/Waiver), whether their mission might require Beyond Visual Line Of Sight (BVLOS) permissions, the flight details, and the payloads. This group examined the different kinds of data collected and their usefulness. These detailed CONOPs would become the "scripts" from which the events conducted under this A52 effort were derived.

Another A28 effort was the assessment of operational risk for various disaster response CONOPs and a determination of specific mitigation measures that might be employed to reduce or eliminate that risk.

## 1.1 Research Questions

There were 11 primary research questions posed in the Research Task Plan:

1. What subset of use cases for the different disaster preparedness and response efforts are representative to demonstrate that UAS can help facilitate response?
2. How did the various agencies, responders, participants, and support personnel coordinate in the demonstrations and the lessons learned to ensure safe operations after a disaster?
3. What are the common risks for the use cases and what are the mitigations to those risks to ensure safe operations for UAS?
4. What are the Concepts Of Operations (CONOPs) and Operational Risk Analysis (ORA) for the specific use cases identified?
5. What category of vehicles will work with each mission type?
6. What are the characteristics of the optimum UAS(s) for disaster preparedness?

7. What should future coordination with FEMA/DOI/DHS look like with UAS integrated into the NAS?
8. What are the considerations for secure Command And Control (C2) links?
9. What are the cyber security considerations?
10. What recommendations can be made for the refinement of requirements, technical standards, policies, procedures, guidelines and regulations needed to enable emergency response operations for use cases using UAS that increase effective, efficient, and safe use of UAS in a disaster?
11. What types of hazards/disasters and scale are best suited for UAS compared with manned flights as the primary investigation tool?

# 2 MOCK EVENTS AND DEMONSTRATIONS

The Research Task Plan for this effort included the provision that the research team would plan, coordinate, and conduct six mock exercises based on the findings of A28 and further research associated with this effort. A table of possible candidates for the exercises included hurricane, flood, tornado, earthquake, fire event, train derailment, terrorist attack at an airport, and health pandemic. Nearly coincident with the submittal of the Research Task Plan, the highest single weekly occurrence of COVID-19 in the United States took place. During the week of January 20, 2022, over 807,000 new cases were confirmed. This immediately raised concern about the idea of bringing large numbers of participants together to conduct major exercises, during which there would be no way to avoid being in close proximity and risking the transmission of the COVID-19 virus.

In the January 2022 Technical Interchange Meeting (TIM), the team made clear that other options were being considered to achieve the end goals of the program, while minimizing the COVID risk to participants. The TIM presentation included a listing and definitions of several options:

- Seminar – Discussion-based training to develop a common framework understanding;
- Workshop with a Tabletop – Designed to train policies and procedures;
- Game – Exercise with hypothetical situations that require specific decisions, and participants are graded on their actions;
- Drill – Field Exercise to demonstrate a specific function repeatedly in order to gain proficiency; and
- Functional Exercise – Field exercises with situations in which decisions are made across multiple entities and the assessment of their decisions are scored with a rubric.

It was pointed out in the TIM that a risk to the program was “COVID 19 causing lack of working meetings, training, and exercises.”

By the time of the February 2022 TIM, the team was engaged in risk mitigation and first presented to the FAA the following concept idea for conducting various alternatives to the full-blown mock exercises:

Table 1. Alternative Event Types, February 2022.

| UAS for Disaster Response Type of Exercise | | | | | | |
|---|---|---|---|---|---|---|
| | Mission Type | Active Exercise | | | | |
| | | Workshop Tabletop | Game | Drill | Functional Exercise | Seminar |
| | Geospatial Mapping | Y | | | | Y |
| | Hotspot, Fire Behavior, Fuels Identification | | | | | Y |
| | SAR | | | | Y | Y |
| | SAR | | | Y | | Y |
| | Flood Map | | | Y | | Y |
| | Airborne Hazard | Y | | | | Y |
| | Airborne Surveillance | | | | Y | Y |
| | Inspection | | | | Y | Y |
| | Delivery / Critical Supply | | | Y | Y | |

During the following months, driven by events and forces beyond the team's control, the list of events was modified. The final number and types of events are presented in Table 2.

Table 2. Final Number and Types of Events.

| **Date(s) of Event** | **Event Category** | **Event Type (Focus)** | **Location** | **Lead Org.** |
|---|---|---|---|---|
| 9-Nov-22 | Seminar | Hurricane/Tornado/Flooding | Huntsville, AL & Zoom | UAH |
| 17-Jan-23 | Seminar | Pandemic: Medical Delivery Between Rural Communities | Zoom | UAF |
| 19-Jan-23 | Seminar | Pandemic: Medical Delivery Between Major Hub and Rural Community | Zoom | UAF |
| 24-Jan-23 | Seminar | Volcanic Eruption | Zoom | UAF |
| 25-Jan-23 | Seminar | Wildland Fire: New Fire in Satellite Data | Zoom | UAF |
| 26-Jan-23 | Seminar | Wildland Fire: Prescribed Burn | Zoom | UAF |

| | | | | |
|---|---|---|---|---|
| 30-Jan-23 | Seminar | Oil Spill | Zoom | UAF |
| 31-Jan-23 | Seminar | Earthquake with Tsunami | Zoom | UAF |
| 22-Feb-23 | Workshop/ Tabletop | Hurricane/Tornado/Flooding | Huntsville, AL | UAH |
| 24-Mar-23 | Drill | Flood Response | Burlington, VT | UVM |
| 29-Mar-23 | Seminar | Train Derailment | Zoom | UVM |
| 30-Mar-23 | Workshop/ Tabletop | Volcanic Eruption | Anchorage, AK | UAF |
| 11-Apr-23 | Workshop/ Tabletop | Earthquake with Tsunami | Anchorage, AK | UAF |
| 14-Apr-23 | Workshop/ Tabletop | Oil Spill | Anchorage, AK | UAF |
| 24-Apr-23 | Workshop/ Tabletop | Wildland Fire: New Fire in Satellite Data | Anchorage, AK | UAF |
| 17-May-23 | Seminar | Airport Terrorism | Huntsville, AL & Zoom | UAH |
| 18-May-23 | Workshop/ Tabletop | Train Derailment | Burlington, VT | UVM |
| 19-May-23 | Drill | Airport Terrorism | Huntsville, AL | UAH |
| 7-Jun-23 | Drill | Landslide | Burlington, VT | UVM |
| 21-Jun-23 | Workshop/ Tabletop | Train Derailment | Burlington, VT | UVM |
| 28-Jun-23 | Functional Exercise | Hurricane/Tornado/Flooding | Tallahassee, FL | UAH |
| 11-Jul-23 | Functional Exercise | Flood Response | Montpelier, VT | UVM |
| 8-Sep-23 | Functional Exercise | Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) | Fairbanks, AK to Nenana, AK | UAF |
| 23-Sep-23 | Functional Exercise | Pandemic: Medical Delivery Between Rural Communities Small UAS (sUAS) | Bethel, AK | UAF |
| 19-24-Oct-23 | Drill | Landslide | Smuggler's Notch, VT | UVM |
| 1-Feb-24 | Seminar | Train Derailment | Burlington, VT | UVM |
| 12-Mar-24 | Workshop | Train Derailment | Burlington, VT | UVM |
| 28-Mar-24 | Workshop | Train Derailment | Burlington, VT | UVM |
| 2-Apr-24 | Functional Exercise | Train Derailment | Burlington, VT | UVM |
| 3-5-Sep-2024 | Functional Exercise | Wildland Fire: Controlled Burn | Pontotoc, MS | NMSU and MSU |

A total of 29 events, including six functional exercises substituted for the originally conceived six mock exercises. The details and findings of those events are presented in the sections below.

## 2.1 11/9/2022, Seminar, Hurricane/Tornado/Flooding, Huntsville, AL, Conducted by UAH

On November 9, 2022, a seminar focusing on hurricanes, tornadoes, and flooding was conducted in Huntsville, Alabama, by personnel from the UAH as part of A52. The seminar was led by Mr. Jerry Hendrix, Director of UAS Systems within the University's Rotorcraft Systems Engineering and Simulation Center. There were 23 individuals attending in person and 17 online via ZOOM. These individuals represented six universities, Huntsville law enforcement, the Alabama Department Of Transportation (ALDOT), FEMA, FEMA Missouri Task Force 1, the FAA, United States Army (PM Unmanned Aircraft Systems) industry at large, Civil Air Patrol (CAP), Madison County Emergency Management Agency, and the National Aeronautics And Space Administration (NASA).

### *2.1.1 Objectives of the Hurricane/Tornado/Flooding Seminar*

The seminar in November 2022 focused predominantly on UAS operations performed during the response efforts in the aftermath of Hurricane Ian by CAP strike teams embedded with FEMA Urban Search And Rescue (USAR) in Fort Meyers Beach, FL. Casey Calamaio from the UAH team volunteered as a UAS Mission Pilot for CAP and activated to Fort Meyers Beach for two weeks. Upon returning, Calamaio presented his experience for the Alliance For System Safety Of UAS Through Research Excellence (ASSURE) seminar to a diverse audience of local/state Emergency Management Agencies, industries, and other government partners.

### *2.1.2 Planning for and Logistics of the Hurricane/Tornado/Flooding Seminar*

The Hurricane/Tornado/Flood seminar was hosted in conjunction with a local monthly meeting about UAS technologies by the Association Of Uncrewed Aircraft System International (AUVSI) Pathfinder chapter in Huntsville, AL. The monthly meeting consisted of both in-person attendance and teleconference via Zoom.

### *2.1.3 Hurricane/Tornado/Flooding Seminar Execution*

This seminar took advantage of recent activation amongst team members to a large-scale hurricane incident to showcase in detail how UASs are used by FEMA. In partnership with the local AUVSI Pathfinder chapter, the delivery of the seminar was received by a diverse audience from across the UAS industry and government affiliates. The seminar was roughly two hours in length including questions and in-depth discussion of UAS in the context of hurricane relief efforts.

### *2.1.4 Hurricane/Tornado/Flooding Seminar Follow-Up Activities, If Applicable*

Advertisement of follow-up ASSURE activities involving Hurricane/Tornado/Flooding was a topic of discussion, specifically the workshop for this task scheduled for February 2023.

### *2.1.5 Lessons Learned from the Hurricane/Tornado/Flooding Seminar:*

#### 2.1.5.1 Hurricane/Tornado/Flooding Seminar Key findings:

1. From Justin Adams, FEMA Missouri Task Force 1: In emergency response, based on experience in Florida and elsewhere:
    a. No one seemed to care about the presence of drones.
    b. Non-cooperative aircrafts are a real problem.
    c. Currently, the only way to integrate is by eyeballs.
    d. Part of the problem is the lack of discipline among the vast number of UAS.

    e. Mr. Adams characterized it as the “Wild, wild, West.”
2. Command staff gets too involved in operational details.
3. There is a need for protocols for use by operational organizations to avoid airspace conflicts.
4. From New Mexico State University (NMSU):
    a. There is a need for research on how close UAS can be flown safely in proximity to manned aircraft.
    b. The Marine Corps controlled UAS by assigning an individual as Air Traffic Control (ATC) for UAS in a specified operational area. UAS-oriented personnel would strictly monitor and control all UAS traffic in the working area while also deconflicting with crewed aircraft.
        i. UAS should report to the UAS Joint Terminal Attack Controller (UAS-JTAC) and get permission for flight after providing general flight information.
        ii. UAS-JTAC constructs an Airspace Coordination Area or Restricted Operations Zone for UAS in the flight area of UAS.
        iii. UAS-JTAC presents information to Manned-JTAC and ensures deconfliction.
        iv. UAS land and launch on UAS-JTAC command (whether they like it or not)
        v. Ensures at least 2 of the “points of deconfliction” are met: Altitude, Position, Orientation, and Time.
    c. Could the FAA consider training some kind of Junior ATC for emergency response situations?
    d. Safety should be emphasized.
    e. All emergency response personnel should go through emergency medical service training.
5. There is a need for someone on the ground in charge of all military assets .
6. It is crucial to work within the FEMA Incident Command System (ICS).

#### 2.1.5.2 Seminar, Hurricane/Tornado/Flooding Recommendations:

- Research is needed on how close UAS can be flown safely in proximity to manned aircraft.
- The FAA might consider training a Junior ATC for emergency response situations.
- All emergency response personnel should go through emergency medical service training.
- When the military is involved in a disaster response, someone on the ground should be in charge of all military assets (JTAC).
- It is crucial to work within the FEMA ICS.

#### 2.1.5.3 Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. In this event, use cases included maintaining Situational Awareness (SA) through use of a persistent oversight UAS, Search And Rescue (SAR) missions, and directed real-time observation of specific rapidly developing targets.
2. Seminar participants agreed on the importance of following the FEMA-recommended ICS due to its familiarity and capacity to expand or contract to best respond to changing situational requirements.

It was recommended that if military assets are employed as part of disaster response, that they have a separate control organization that equates to a JTAC.

3. Common risks include aircraft in-flight collision with other UAS due to proximity flying and loss of aircraft due to poor battery management. Mitigations are to separate UAS as far as possible when assigning tasks, have designated, trained and qualified visual observers assigned to each Pilot In Command (PIC) and to have at least one individual on the response team responsible for battery management.
4. CONOPs in an event of this nature is usually the use of multicopters carrying visual sensors with real time display. When conducting SAR, thermal imagery may be employed to locate heat sources. The ORA for this type of CONOP is described in question three above.
5. For the general survey and the SAR mission, a multicopter capable of lifting the imaging device and having a battery life appropriate to the mission are the prerequisites. Proven reliability of the aircraft and its control system are also necessary attributes.
6. Discussion of this subject by the participants highlighted long battery life and the ability to capture high-quality imagery as desirable characteristics for a disaster response aircraft. Reliability was also stressed. Another factor mentioned was that larger aircraft seem to fare better in stormy conditions and are more stable, enabling better images to be delivered.
7. This seminar was held as part of a lead up to the full-scale FEMA hurricane/flooding exercise later in the year, entitled Catastrophic UAS Remote Sensing Exercise (CURSE). As a consequence, much of the seminar discussion was related to how such an exercise might be organized. This exercise became a poster child for how such an event, involving dozens of dissimilar organizations, should be run. The organizers insisted that all the rigor of FEMA's internal discipline be used – the ICS, expansive use of checklists and procedures, disciplined and orderly communications, and precise definition of organizational roles. This same level of controlled integrated activity will be required to integrate UAS on a large scale into the NAS.
8. Secure C2 links were not addressed in the seminar.
9. Cyber security was raised as a topic in the seminar, but the discussion centered on how disruptive it would be and how difficult it would be to prevent or work around. The subject of control system vulnerability to cyberattacks was discussed, but no remedy was identified.
10. The most frequent opinion rendered at the seminar was the need for strict adherence to process (as in checklists) and discipline to be effective contributors to disaster response. The structure and discipline demanded by FEMA during a major disaster, in operations, communications, reporting, role definition, and precise tasking are all components that could be incorporated into requirements, technical standards, policies, procedures, guidelines, and regulations that would increase the effective, efficient, and safe use of UAS in a disaster.
11. Flights near structures and infrastructure, low-level flying for damage assessment or search-and-rescue, or flight in or around hazardous materials are ideal for UAS as compared with manned aircraft. The UAS becomes a proxy for a human pilot and makes it unnecessary to place human pilots in dangerous situations.

#### 2.1.5.4 Seminar, Hurricane/Tornado/Flooding Seminar Lessons Learned Summary

The discussion at this seminar covered an extremely broad spectrum of topics. People who were practitioners of emergency response were very forthcoming with anecdotes and opinions of the discipline and structure needed for the safe integration of UAS into the NAS during disaster response. The current status was referred to as the “Wild West” because of the presence of untrained UAS operators who appear during disasters.

## 2.2 1/17/2023, Seminar, Pandemic: Medical Delivery Between Rural Communities, ZOOM, Conducted by UAF

### *2.2.1 Objectives of the Pandemic: Medical Delivery Between Rural Communities Seminar*

This was a use case for delivering medical supplies between two rural communities that are inaccessible by other means from the road network or river crossing/access. The early stages of the COVID-19 pandemic were used as part of the case. The seminar was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case.

### *2.2.2 Planning for and Logistics of the Pandemic: Medical Delivery Between Rural Communities Seminar*

The seminar was held online via Zoom. Google and Microsoft team forms were used to have potential attendees sign up and receive the Zoom login data. University of Alaska Fairbanks’ Alaska Center For UAS Integration (UAF-ACUASI’s) network of collaborators and those signed up to the Interest User group were used to showcase the seminar as well as the wider A52 team’s connections and UAS network. 29 people signed up and 25 attended the seminar.

### *2.2.3 Pandemic: Medical Delivery Between Rural Communities Seminar Execution*

The seminar was one hour long, and attendees followed a slide presentation by Professor Webley from UAF-ACUASI. The attendees also completed a Mentimeter survey on their current capabilities and knowledge of UAS as applied to this use case. The survey only collected responses based on the organization type and position type of the attendees and did not capture personally identifiable information.

### *2.2.4 Lessons Learned from the Pandemic: Medical Delivery Between Rural Communities Seminar, Including Responses to Research Questions*

#### 2.2.4.1 Pandemic: Medical Delivery Between Rural Communities Seminar Key findings:

1. Most of the coordination would occur between the medical facilities sending and receiving the supplies. (These facilities would likely be part of the same medical organization and as such, coordination would occur within the organization.)
2. Depending on the flight requirements such as altitude, Visual Line Of Sight (VLOS), or BVLOS, there may need to be coordination between the flight crew and the FAA to obtain the permissions needed for safe operations under Part 107.
3. The aircraft may be classified as carrying cargo and therefore would need relevant permissions for the operator and operator organization to carry the supplies.

#### 2.2.4.2 Pandemic: Medical Delivery Between Rural Communities Seminar Recommendations:

For pandemic use cases such as the focus in this CONOPs, there are specific components of the event where UAS are best suited that minimize risk to ground teams and medical professionals:

- Rapid operations across river locations when no other ground transport is allowed.
- Moving supplies from warehouse, hospital, or clinic to smaller locations when needed.

- Getting the medical supplies to where they are needed and not being limited by the weather conditions, geographical environment, or logistical issues caused by the pandemic event.

#### 2.2.4.3 Pandemic: Medical Delivery Between Rural Communities Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. The important roles that UAS provide for this pandemic event are as follows:

   *Moving essential supplies*: During an event like the 2020 stage of the COVID-19 pandemic, there was little to no ground movement of personnel or vehicles as well as no ability to travel to a rural Alaskan community from the main communities of Fairbanks, Anchorage, or Juneau. Therefore, moving supplies by air and ideally by UAS would allow these communities to still get the medical supplies to those in need and on time.

   *Minimizing interactions between communities:* UAS provide an airborne-based platform to move supplies around Alaska. Small UAS (sUAS) can be up to 55 lb. of take-off weight which allows for sizeable payloads along with the aircraft airframe. They can fly over significant distances and for several hours. Therefore, they provide an ideal tool to minimize movement between communities when a pandemic event, like the early stages of COVID-19, is in full force.

2. This use case would include several different organizations in the two communities to ensure that the UAS can transport the medical supplies between them. One lesson learned is that for follow-on demonstrations, nursing and medical students should be included. These students will become the nurses and doctors of the future, when UAS could become part of the medical delivery transportation network like helicopters and ambulances are used now. Another lesson learned is the available information provided to medical practitioners that accompany the UAS to be used in medical deliveries. The practitioners may not be UAS pilots or operators and will need some manuals and support in how to effectively use the UAS and add the medical supplies to the system payload.
3. A general ORA for risks that could impact all use cases under A52 and a specific ORA for this use case are coupled to event response. Several risks were highlighted by the attendees:

   Available UAS pilots and systems: This use case is for medical supply delivery between two rural communities. Therefore, for the UAS to be an effective tool then there needs to be local Part 107 pilot operators and available systems in the communities at risk. Getting a flight crew to arrive at the main medical location would not be possible under the 2020 COVID-19 pandemic environment. Today, there would be a major impact on medical supply delivery if the flight crew had to travel from another location to be able to perform the mission to get the supplies from one community to the next.

4. Attendees noted a need for training to be provided to medical practitioners on the capabilities and capacity of sUAS. This would be included in the community outreach as part of a CONOPs. For the ORA, one possible risk would be that there are no medical personnel on duty that has worked with UAS for medical deliveries and as such there could be a delay in getting the supplies into the payload ready for flight. Therefore, a mitigation and action plan is to provide sufficient manuals and operating procedures so that medically trained personnel can

load the supplies and also ensuring that during any given shift there is at least one person with the background and training to operate the UAS and load the supplies as well as unload and operate the drone at the landing site.

5. A sUAS would be sufficient for this mission. This would also support the flight crew to fly under Part 107 regulations[1], where possible. Depending on the supplies being carried and flight routes, additional permissions and requirements would be placed on the flight crew to ensure safe and legal operations in the NAS.
6. For this use case, the defined UAS is a small less than 55 lb. aircraft. Given the flight time, take-off and landing sites and altitude, it could be a Vertical Take Off And Landing (VTOL), VTOL and fixed wing, or fixed wing system. Its main goal is to take the medical supplies from the medical clinic/hospital/warehouse to the location where they are needed and then return. Therefore, the available power and system endurance are considerations when determining the optimal system to support this use case of moving medical supplies between two rural communities during a pandemic.
7. Most of the coordination would occur between the medical facilities sending and receiving the supplies. These facilities would be part of the same medical organization and as such coordination would occur with the organization. Depending on the flight requirements such as altitude, VLOS, or BVLOS, there would need to be coordination between the flight crew and FAA to obtain the permissions needed for safe operations. The aircraft may be classified as carrying cargo and would need relevant permissions for the operator and operator organization to carry the supplies.
8. There was no direct reference to C2 links in the seminar. As with the cyber security considerations, there are important details to ensure safe flight operations from the take-off location at the original medical clinic/hospital as well as the drop-off location. Additionally, the aircraft will be returning to the original location for future use and so there will be a take-off at the remote medical location back to the main site for more medical deliveries. Can the take-off ground station keep continued communications with the aircraft or is there a need for a second ground control station?

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[1] The FAA rules for sUAS, or "drone," operations cover a broad spectrum of commercial and government uses for drones weighing less than 55 pounds. Highlights of the rule, 14 CFR Part 107, include: Always avoid manned aircraft, Never operate in a careless or reckless manner. Keep your drone within sight. If you use First Person View or similar technology, you must have a visual observer always keep your drone within unaided sight (for example, no binoculars). You cannot be a pilot or visual observer for more than one drone operation at a time. Do not fly a drone over people unless they are directly participating in the operation. Do not operate your drone from a moving aircraft. Do not operate your drone from a moving vehicle unless you are flying your drone over a sparsely populated area and it does not involve the transportation of property for compensation or hire. You can fly during daylight (30 minutes before official sunrise to 30 minutes after official sunset, local time) or in twilight if your drone has anti-collision lighting. Minimum weather visibility is three miles from your control station. The maximum allowable altitude is 400 feet above the ground, higher if your drone remains within 400 feet of a structure. Maximum speed is 100 mph (87 knots). Your drone can carry an external load if it is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft. You also may transport property for compensation or hire within state boundaries provided the drone (including its attached systems), payload, and cargo, weighs less than 55 pounds total and you obey the other flight rules. (Some exceptions apply to Hawaii and the District of Columbia.) You can request waiver of most restrictions if you can show your operation will provide a level of safety at least equivalent to the restriction from which you want the waiver. Some of the most requested waivers are for operations BVLOS, during nighttime, and over people.

9. For this case, there are concerns in terms of the medical supplies being transported and their security between the two sites, when there could also be personal identifiable information onboard as well as sensitive supplies. Ensuring that no bad actors can "hack" the flight and access the supplies when the UAS is transiting between the two locations will be essential for flight security on medical front but also on the safe operations of the UAS in the NAS.
10. For this case, there is a need to move medical supplies between two rural locations during a pandemic event. Below are two recommendations from the attendee's response to this use case:
    - *Ensuring sUAS pilots and systems in rural communities:* Having pilots in the communities across Alaska and other rural sites in the US is essential for this use case to transition into day-to-day operations. Waiting for the crews to come from other sites just to perform the mission adds additional time to the medical needs with significant impacts on the safety of those concerned. Therefore, having Part 107 pilots and systems with payload capacity in the local communities is essential. The organizations moving the medical supplies need to have all permissions in place to safety and legally perform the missions, as they will be carrying cargo between the two sites.
    - *Ensuring medical professionals are trained in how to engage with UAS:* When loading and unloading sensitive medical supplies, there is a need to have medically trained personnel performing these duties. Just as for loading and unloading medical supplies for ground transportation, there is a need for personnel in both locations to be trained to work with the UAS, especially their payload systems. Also ensuring that there is at least one person per shift who has the training to support the implementation of the UAS into the day-to-day activity of the medical facilities.
11. For pandemic use case such as the focus in this CONOPs, there are specific components of the event where UAS are best suited that minimizes risk to ground teams and medical professionals:
    - Rapid operations across river location when no other ground transport is allowed.
    - Moving medical supplies from warehouse, hospital, or clinic to smaller locations when needed.
    - Getting the medical supplies to where they are needed and not being limited by the weather conditions, geographical environment, or logistical issues caused by pandemic event.

#### 2.2.4.4 Pandemic: Medical Delivery Between Rural Communities Seminar Lessons Learned Summary:

Attendees at the seminar noted that there is a need for training to be provided to medical practitioners on the capabilities and capacity of sUAS. This would be included in the community outreach as part of a CONOPs. A sUAS would be sufficient for this mission. This would also support the flight crew to fly under Part 107 regulations where possible. For this use case, most of the coordination would occur between the medical facilities sending and receiving the supplies. These facilities would likely be part of the same medical organization and, as such, coordination would occur within the organization. This use case would include several organizations in the two communities to ensure that the UAS can transport the medical supplies between them. One lesson learned is that for follow on demonstrations, nursing and medical students should be included.

## 2.3 1/19/2023, Seminar, Pandemic: Medical Delivery Between Major Hub and Rural Community, ZOOM, Conducted by UAF

### *2.3.1 Objectives of the Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar*

This is a use case for delivering medical supplies between a major medical hub and a rural community in need of supplies that is inaccessible by other means from the road network or river crossing/access. The early stages of the COVID-19 pandemic were used as part of the case. The seminar was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case.

### *2.3.2 Planning for and Logistics of the Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar*

The seminar was held online via Zoom. Google and Microsoft Teams forms were used to have potential attendees sign up and receive the Zoom login data. UAF-ACUASI's network of collaborators and those signed up to the Interest User group were used to showcase the seminar as well as the wider A52 team's connections and UAS network. 27 people signed up and 21 attended the seminar.

### *2.3.3 Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar Execution*

The seminar was one hour long, and attendees followed a slide presentation by Professor Webley from UAF-ACUASI. Additionally, all attendees were asked to complete a Mentimeter survey to record relevant knowledge and capabilities regarding the use of UAS in this specific use case. The survey only collected information about the organization and position type of the attendees—no personally identifiable information was recorded.

### *2.3.4 Lessons Learned from the Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar, Including Responses to Research Questions*

#### 2.3.4.1 Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar Key findings:

1. The UAS is a large UAS (lUAS) with sufficient payload. Given the flight time, take-off and landing sites and altitude, it could be a VTOL and fixed wing, or fixed wing system.
   a. Its main goal is to take the medical supplies from the medical clinic/hospital/warehouse to the location where they are needed and return. Therefore, the available power and system endurance are considerations when determining the optimal system to support this use case of moving medical supplies between two rural communities during a pandemic.

#### 2.3.4.2 Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar Recommendations:

- Ensure that there are personnel in the rural community that can remove the cargo from the lUAS and administer any vaccines. Without personnel to perform these duties, then the aircraft will arrive at the rural community, but the community will not be able to benefit from the supplies transported to them.

#### 2.3.4.3 Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. *Moving essential supplies:* During an event like the 2020 stage of the COVID-19 pandemic, there was little to no ground movement of personnel or vehicles as well as no ability to travel to a rural Alaskan community from the main communities of Fairbanks, Anchorage, or Juneau. Therefore, moving supplies by air and ideally by UAS would allow these communities to get the medical supplies to those in need and on time.

   *Minimizing interactions between communities:* UAS provide an airborne-based platform to move supplies around Alaska. lUAS provide an increased payload capacity and ability to carry both in-need medical supplies as well as cargo for long-term response and preparedness. Therefore, lUAS provide an ideal tool to minimize movement between communities when a pandemic event, like the early stages of COVID-19 and support the rural community in preparation for long periods of isolation.

2. This use case includes several different organizations in both communities to ensure that the UAS can transport the medical supplies between them. One lesson learned is to ensure that there are personnel in the rural community that can remove the cargo from the lUAS and administer any vaccines. Without personnel to perform these duties, then the aircraft will arrive at the rural community, but the community will not be able to benefit from the supplies transported to them. For flight operations, several additional sensors would be needed to ensure mission success. If the flight must occur under Instrument Flight Rules (IFR) only then a thermal sensor would be essential and be included as a default sensor on the aircraft. This would support the flight crew to continue flight operations and allow the lUAS to land, deliver its cargo, take-off, and return to the main hub. Secondly, there should be a meteorological sensor on board the lUAS to provide real-time data to the ground crews to support safe flight operations and provide data to mitigate the impact that could occur from icing on lUAS platforms.
3. A general ORA for risks that could impact all use cases under A52 and a specific ORA for this use case are coupled to event response. Several risks were highlighted by the attendees:

   *Available crew to remove cargo:* This use case is for medical supply delivery between a major hub and a rural community. Therefore, for the UAS to be an effective tool then there needs to be local operators in the community at risk. Getting a specialist crew to arrive at the drop-off location would not be possible under the 2020 COVID-19 pandemic environment. Today, there would be a major impact on medical supply delivery if the flight crew had to travel from another location to perform the mission to get the supplies from one community to the next.

4. Attendees noted that there is a need for training to be provided to medical practitioners on the capabilities and capacity of the UAS, especially those in the rural community who would unload the cargo and provide the secondary flight crew. One possible risk would be that there are no medical personnel on duty that have worked with UAS for medical deliveries and as such there could be a delay in getting the supplies from the payload. A mitigation and action plan to provide sufficient manuals and operating procedures is needed so medically trained personnel can unload the supplies and ensure there is at least one person with the background

and training to operate the UAS and load the supplies as well as unload and operate the drone at the landing site.

5. A lUAS would be needed. A system with sufficient flight time to travel from the main hub to the community and back would be needed. A fixed wing or VTOL with fixed wing capabilities would be options with all payload capacity to carry the needed cargo and medical supplies.
6. For this use case, the defined UAS is a lUAS with sufficient payload. Given the flight time, take-off and landing sites and altitude, it could be a VTOL and fixed wing, or fixed wing system. Its main goal is to take the medical supplies from the medical clinic/hospital/warehouse to the location where they are needed and return. Therefore, the available power and system endurance are considerations when determining the optimal system to support this use case of moving medical supplies between two rural communities during a pandemic.
7. For this use case, most of the coordination would occur between the medical facilities sending and receiving the supplies. These facilities would likely be part of the same medical organization and, as such, coordination would occur within the organization. Depending on the available UAS, this would also include the airports where the aircraft may have to take-off and land. Depending on the flight requirements such as altitude, VLOS, or BVLOS, then there may need to be coordination between the flight crew and the FAA to obtain the permissions needed for safe operations. Additionally, the aircraft will be classified as carrying cargo and would need relevant permissions for the operator and operator organization to carry the supplies.
8. There was no direct reference to C2 links in the seminar. As with the cyber security considerations, there are important details to be evaluated to ensure safe flight operations from the take-off location at the original medical clinic/hospital as well as the drop-off location. The aircraft will be returning to the original location for future use so there will be a take-off ground crew at the remote medical location ready to support the aircraft to get back to the main site for more medical deliveries.
9. For this case, there are concerns in terms of the medical supplies being transported and their security between the two sites, when there could be personal identifiable information onboard as well as sensitive supplies. Ensuring that no bad actors can “hack” the flight and access the supplies when the UAS is transiting between the two locations will be essential for flight security on the medical front but also for the safe operations of the UAS in the NAS.
10. For this case, there is a need to move medical supplies between a main hub and a rural location during a pandemic event. Below are recommendations from the seminar attendees:
    - *Ensuring sensors on board to perform IFR missions:* For this use case, there is a need to always get medical supplies into the rural community, irrespective of the weather conditions. As such, a UAS with only a visible camera to supplement the navigation tools would limit the conditions which the aircraft could fly in. Adding in a thermal camera as part of the sensor packages on-board would ensure the necessary data to couple with the aircraft navigational systems and Detect And Avoid (DAA) sensors.
    - *Ensuring medical professionals are trained in how to engage with UAS:* When loading and unloading sensitive medical supplies, there is a need to have medically trained personnel performing these duties. Just as for loading and unloading medical supplies for ground transportation, there is a need for personnel in both locations to be trained to work with the UAS, especially their payload systems. Also ensuring that there is at least one person per

shift who has the training to support the implementation of the UAS into the day-to-day activity of the medical facilities.

11. For pandemic use cases such as the focus in this CONOPs, there are specific components of the event where UAS are best suited to minimize risk to ground teams and medical professionals:
    - Rapid operations across river locations when no other ground transport is allowed.
    - Moving supplies from warehouse, hospital, or clinic to smaller locations when needed.
    - Getting the medical supplies to where they are needed and not being limited by the weather conditions, geographical environment, or logistical issues caused by pandemic events.

##### 2.3.4.4 Pandemic: Medical Delivery Between Major Hub and Rural Community Seminar Lessons Learned Summary:

This use case would include several different organizations in both communities to ensure that the UAS can transport the medical supplies between them. One lesson learned is to ensure that there are personnel in the rural community that can remove the cargo from the lUAS and administer any vaccines. Without personnel to perform these duties, then the aircraft will arrive at the rural community, but the community will not be able to benefit from the supplies transported to them. Attendees noted that there is a need for training to be provided to medical practitioners on the capabilities and capacity of the UAS, especially those in the rural community who would unload the cargo and provide the secondary flight crew.

## 2.4 1/24/2023, Seminar, Volcanic Eruption, ZOOM, Conducted by UAF

### *2.4.1 Objectives of the Volcanic Eruption Seminar*

The scenario for this use case was a volcanic eruption from Mt. Spurr in Alaska along with volcanic ash moving across Anchorage and South-Central Alaska. The seminar was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case.

### *2.4.2 Planning for and Logistics of the Volcanic Eruption Seminar*

The seminar was held online via Zoom. Google and Microsoft Teams forms were used to have potential attendees sign up and receive the Zoom login data. UAF-ACUASI’s network of collaborators and those signed up to the Interest User group were used to showcase the seminar as well as the wider A52 team’s connections and UAS network. 46 people signed up and 32 attended the seminar.

### *2.4.3 Volcanic Eruption Seminar Execution*

The attendees completed a Mentimeter survey on their current capabilities and knowledge of UAS as applied to this use case. The survey only collected responses based on the organization type and position type of the attendees and did not capture personally identifiable information.

### *2.4.4 Lessons Learned from the Volcanic Eruption Seminar, Including Responses to Research Questions*

##### 2.4.4.1 Volcanic Eruption Seminar Key findings:

1. There is no one optimum UAS to support all aspects of the volcanic use case and provide all necessary observations to support the response.

2. sUAS can provide rapid response observational data that can operate from a small-footprint take-off zone and can be carried by a team to get to locations not possible by crewed systems or lUAS.
3. It would be hard for a ground team to reach the summit for sUAS operations while the volcanic ash and gases would limit flight operations to BVLOS.
4. Sensors onboard provide specific observational needs, either visible cameras to build Structure from Motion (SfM) 3D models, thermal sensors to determine heat flux from the event and/or flow speed, and ash and gas samples to assess the changing volcanic signals and support decision makers on the likelihood for an increase or decrease in activity levels.
5. lUAS can provide a high-altitude observational dataset not possible from small rotor UAS systems and can be flown to targeted locations for the need of the event response.

#### 2.4.4.2 Volcanic Eruption Seminar Recommendations:

For a volcanic eruption use case, UAS can provide additional capabilities that would be difficult to collect from manned flights. These include:

- Long-term high-altitude observations of the full extent of the volcanic event.
- Continued night-time operations when manned systems are unable to operate.
- Rapid response events with ability to switch out sensors for situational awareness.
- Access to summit to support decision making when risk is too high for manned systems.

#### 2.4.4.3 Volcanic Eruption Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. *Real-time Situational Awareness:* During the seminar, it was noted that a sUAS could provide proximal and close access to the area when a ground-based team would be unable. This UAS could provide thermal and visible data and observations from the active region and prevent the ground teams from being put at risk.
2. It's all about the location of the event. One component for consideration from the seminar was:

   *Safety plan and access to volcano:* Depending on the location of the eruption, access may be limited and/or safe landing zones required to respond to hazards during flight may be in areas of limited access. Communicating on likely safe zones for UAS with decision-makers mitigated the chance of unexpected landings in inaccessible sites. Additionally, for this use case, the volcano's summit is at 11,000 ft Above Ground Level (AGL), and therefore to map the full extent of the volcanic products, a high latitude lUAS would be required.

3. Two risks were discussed that were not included in the general or specific operational risk assessment shown to the workshop participants.
   - *Need for a Temporary Flight Restriction[2] (TFR):* For an event such as a volcanic eruption, response organizations will want to prevent access to the summit and highly active region. Given the location of the volcano in this use case as well as other active volcanoes in the Cook Inlet, Alaska, then a TFR would be needed. With an active air

[2] A Temporary Flight Restriction (TFR) is a type of Notices to Airmen (NOTAM). A TFR defines an area restricted to air travel due to a hazardous condition, a special event, or a general warning for the entire FAA airspace. The text of the actual TFR contains the fine points of the restriction.

traffic corridor and airspace around Anchorage, a TFR will limit any other aircraft and assist those responding to the event to be able to map the active area and make informed decisions about the ongoing hazard and its future activity levels.

- *Volcanic hazard (Ash/SO2/CO2) Degradation:* Significant volcanic hazardous material impacts the airframe and payload while in flight that making the aircraft of limited use or unsafe to use. This will cause the flight crew to be unable to support the operational needs of those in the response. Flight crew will mitigate this through cleaning of systems between flights, minimizing the chance of debris hitting the aircraft in flight, and vigorous assessment of the airframe and payloads after each flight.

4. The CONOPs and ORA were developed by the A52 team for a volcanic eruption from Mt. Spurr Volcano in South-Central Alaska with an eruptive vent at the summit and attached plume as well as dispersing ash clouds towards Anchorage. A general hazards ORA that could occur in all use cases under A52 and specific hazards ORA for this use case were developed to accompany the CONOPs. Additionally, a quad chart and a suite of checklists were added to the CONOPs and two ORAs.
5. A lUAS would provide higher altitude observations of the volcanic event and be able to sample the plume from the summit vent. A sUAS would be flown from the summit region to provide precision observations of the ground hazards at this location and vertical profiles through the plume. A sUAS would provide downwind ash and gas measurements to support the decision team in predicting the cloud impact on Anchorage and its surrounding infrastructure.
6. There is no one optimum UAS to support all aspects of the volcanic use case and provide all necessary observations to support the eruption response. sUAS systems can provide rapid response observational data that can operate from a small-footprint take-off zone and can be carried by a team to get to locations not possible by crewed systems or lUAS. It was noted during this seminar that it would be hard for a ground team to reach the summit for sUAS operations while the volcanic ash and gases would limit flight operations to BVLOS only. Sensors onboard provide specific observational needs, either visible cameras to build SfM 3D models, thermal sensors to determine heat flux from the event and/or flow speed, and ash and gas samples to assess the changing volcanic signals and support decision makers on the likelihood for an increase or decrease in activity levels. A lUAS can provide a high-altitude observational dataset not possible from small rotor UAS systems and can be flown to targeted locations at the need of the event response.
7. For this use case, organizations wanting to integrate UAS into the event response and the NAS will need to follow local ICS and local and regional eruption response protocols for responsible agencies and communication structure. For the volcanic use case, agencies responsible for the event response should follow the regional interagency coordination plans that provide details on all responsible groups and points of contact. As UAS continue be used as a research tool for the volcanic community, they will be available for event response. As such plans are needed for how these will support volcanic event responses and who will manage the fleet of aircraft, just as is done for crewed systems today to move resources and gain access to the volcanic summit region.
8. There was no direct reference to C2 in the seminar. Airspace coordination, specifically having a TFR in place, was stated as important given the number of crewed and uncrewed systems.

9. Ensuring a safe network of UAS is highlighted in the ORA and having a flight crew able to mitigate against any bad actors wanting to take control of the aircraft is a consideration in the ORA but was not discussed at the seminar.
10. For this use case, a volcanic eruption from Mt. Spurr, Alaska, was selected for the event location. While this event may occur soon, operationally UAS/drones have been used at eruptions in Hawaii. One of the seminar attendees has been part of two eruption responses in Hawaii and has seen the application of UAS.

    Ensure all potential airspace coordination procedures are in place as during an event, there is a need to prevent any bad actors and non-essential airborne assets from passing over the volcano summit. Having a TFR in place will mitigate this issue and also support those event response crewed and uncrewed systems from supporting ground crews.
11. For a volcanic eruption use case, UAS can provide additional capabilities that would be difficult to collect from manned flights. These include:
    - Long-term high-altitude observations of the full extent of the volcanic event.
    - Continued night-time operations when manned systems are unable to operate.
    - Rapid response events with the ability to switch out sensors for situational awareness.
    - Access to summit hazard to support decision-making when risk is too high for manned systems.

#### 2.4.4.4 Volcanic Eruption Seminar Lessons Learned Summary:

Organizations wanting to integrate UAS into the event response and the NAS will need to follow local ICS and where set-up local and regional eruption response protocols for responsible agencies and communication structure. For the volcanic use case, agencies responsible for the event response should follow the regional interagency coordination plans that provide details on all responsible groups and points of contact. As UAS continue to be used as a research tool for the volcanic community, they will be available for event response. As such, plans are needed for how these will support volcanic event responses and who will manage the fleet of aircraft, just as is done for crewed systems today to move resources and gain access to the volcanic summit region.

## 2.5 1/25/2023, Seminar, Wildland Fire: New Fire in Satellite Data, ZOOM, Conducted by UAF

### *2.5.1 Objectives of the Wildland Fire: New Fire in Satellite Data Seminar*

This event of a newly detected wildland fire from satellite data led to several different use cases where drones and UAS can operationally support the event response. There are several hazardous impacts to the surrounding landscape and infrastructure where a drone/UAS can minimize putting personnel at risk and supplementing existing assets. The seminar was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case.

### *2.5.2 Planning for and Logistics of the Wildland Fire: New Fire in Satellite Data Seminar*

The seminar was held online via Zoom. Google and Microsoft Teams forms were used to have potential attendees sign up and receive the Zoom login data. UAF-ACUASI’s network of collaborators and those signed up to the Interest User group were used to showcase the seminar as well as the wider A52 team's connections and UAS network. 50 people signed up and 28 attended the seminar.

### *2.5.3 Wildland Fire: New Fire in Satellite Data Seminar Execution*

The seminar was one hour long, and attendees followed a slide presentation by Professor Webley from UAF-ACUASI. At the end of the seminar, the attendees were given a Mentimeter survey on their current knowledge of UAS as applied to this use case. The survey did not capture personally identifiable information, only information regarding organizations and positions.

### *2.5.4 Lessons Learned from the Wildland Fire: New Fire in Satellite Data Seminar, Including Responses to Research Questions*

#### 2.5.4.1 Wildland Fire: New Fire in Satellite Data Seminar Key findings:

1. Any organizations wanting to integrate UAS into the event response, as well as the NAS, will need to follow local incident command structure and abide by local and regional response protocols for responsible agencies and communication structure.
2. One of the attendees spoke about building a wildland fire training program and how this could be a tool to use to effectively integrate UAS into wildland fire response and safe integration into the NAS.

#### 2.5.4.2 Wildland Fire: New Fire in Satellite Data Seminar Recommendations:

- *Operational skills of flight crew:* With such a busy use case, a flight crew should be able to highlight their experience of operating in an event response and around multiple airborne systems, both crewed and uncrewed. This recommendation ensures that the flight crew will then be an asset to the response rather than a hinderance and impact other response teams.
- *Flight teams have incident training:* The flight crew teams should have some level of ICS training. This can be FEMA 100 and 200 independent study as well as national 700 and 800 courses. Also, there is an in-person course, G0191- ICS/ Emergency Operating Center (EOC) interface. This recommendation ensures all members of the flight crew are aware of the event response protocols and can be an additional asset for the response.
- Ensure all flight crew have additional safety equipment as they could come into close contact with wildland fire ash and gases and so would need mitigation devices (air filters with masks) that they could use to continue to operate. Also, crews should know ongoing hazards so could evacuate to safe zones if the fire impacts their flight location including take-off and landing zones. This recommendation ensures the flight crew are safe to operate in and around this hazardous event and can ensure the safety of their crew and not put extra burden on the other event response teams.

#### 2.5.4.3 Wildland Fire: New Fire in Satellite Data Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. This event of a newly detected wildland fire from satellite data led to several different use cases where drones and UAS can operationally support the event response. There are several hazardous impacts to the surrounding landscape and infrastructure where a drone/UAS can minimize putting personnel at risk and supplementing existing assets.

- *Real-time Situational Awareness*: This provides visible and thermal feeds of the ongoing activity. This will support ground teams responding to the new fire and finding where to place ground assets to both monitor and mitigate against the ongoing event. It was also highlighted that drones/UAS can be used post-fire to look for hotspots left from the fire front. Also, the systems could provide knowledge on the local winds at the surface and multiple altitudes to support spot forecasting and lingering term plus dispersal.
- *Post-flight Mapping:* These would be generated post-flight but during the ongoing response. Products would include orthorectified imagery and composite maps (both visible and thermal). Products support decision-making teams during the ongoing event as well as post-fire to assess fire impact on the environment and after-action reviews. Consideration is required for the dissemination of this data including all metadata to ensure it can be visualized by all entities in the response, whether from federal, state, local, academia, or private sector.
- *Real-time Sampling:* The products from wildland fire events, such as ashes, need to be sampled in real-time to assess any changes in the fire activity that can support plume forecasting and to determine the potential dispersal extent of the plume and downwind clouds. This data can also support those in the fire modeling to determine fire activity changes. Consideration is needed on the types of missions, altitudes to be flown including permissions needed, and impact on the aircraft to provide sustained observations to support the operational agencies.
- *Post-mission 3D modeling:* SfM processing from visible and thermal imagery can produce 3D models of the local landscape, especially below cloud cover that prevents satellite mapping or other crewed systems. Coupled visible and thermal 3D model data provides added actionable intelligence on the fire products and if they are still a hazard to the local population and infrastructure.

2. Communication is key. For this event, the detected fire most likely will be in a remote location and there may be many airborne assets operating in the area with one central operations center or EMOC with an air boss/air coordinator. Ensuring that the teams are all aware of the airspace environment and involved in all daily briefings limits the impact of a lack of communication where a flight team might be a hindrance to operations.

The team will need to know air traffic in the areas, if TFR is in place, and if so, where. The team will need to coordinate with the Air Boss. The team will need waivers to get in and out of TFR, if take-off is not in TFR zone. The team should carry copies of all teams' 107 permissions. One component that came up in the workshop discussions was communication channels. What are the communication channels being used? Where are all other manned/crewed systems supporting the response? Ensure no cross communications between teams and all follow ICS procedures. The response will be a complex event and the team will need to show that they can operate safely in this type of operation.

3. Seven risks came up for discussion that were not included in the general or specific ORA shown to the workshop participants:
   a. *Change in winds leads to fire spread and plume dispersal:* During the event, the fire may spread towards the UAS takeoff and landing site while the dispersing plume may move to put the flight crew at risk and unhealthy atmospheric conditions. This causes the team to

be at risk and therefore impacts for safe flight operations of the UAS in the NAS. Flight crew will mitigate this by keeping in communications with central operations to stay informed on fire spread and plume dispersal. Where needed, the crew will move operations to a safe location and stop the flight to ensure safe operations with a DLI or Return To Landing (RTL). Action ensures safe operations and a safe flight crew.

b. *Crewed and uncrewed all together in the same airspace:* Given the busy operations to respond to this event, there may be numerous assets in the air. An uninformed crew may have a crewed system enter their airspace and planned route as well as have other uncrewed systems passing through their airspace. Flight crew will mitigate this by staying in communication with the air boss/air operations lead to be aware of all airborne operations as well as have a visual observer monitoring the UAS and the airspace around the operations. If needed to ensure safe operations, a flight will RTL or DLI following their action plans. Action ensures safe operations in the NAS.
c. *Lack of knowledge of the location of ground response crews:* The flight crew operating the UAS is unaware of the ground teams responding to the fire and mitigating its spread. As a result, the flight crew could put their operations at risk as well as other airborne assets and the ground crew at risk. Flight crew will mitigate this by ensuring they have communications with the central operations to have knowledge of current ground teams and be integrated into all briefings before day operations to they are aware of ground team movements and plans for fire mitigation. Action will ensure that no person or equipment is put at risk. If there are other assets near flight operation, the crew will follow DIL or Return To Base (RTB) actions to ensure safe operations in NAS.
d. *Heat from fire impacts flight operations including thermals:* There is a change in intensity and the heat from the rapidly growing fire puts the UAS at risk that impacts safe operations in the NAS and completing the mission. Flight crew will mitigate against this by monitoring the location of the fire front and plume emitted from the spreading fire as well as staying at a safe altitude above the fire to limit the potential for this hazard. This action ensures safe operations, equipment to continue operating, and the crew completing their mission as requested to support the fire response.
e. *Impact of fire ash on airframe and all components:* Significant fire-based ashes impact the airframe and payload while in flight that makes the aircraft of limited use or unsafe to use. This will cause the flight crew to be unable to support the operational needs of those in the response. Flight crew will mitigate this through cleaning of systems between flights, minimizing the chance of debris hitting the aircraft in flight, and vigorous assessment of the airframe and payloads after each flight.
f. *Risk of health of crew from poor air quality at ground:* Given the event response centered on support of a wildland fire, there is the potential that the air quality at the flight crew’s location will deteriorate to unhealthy conditions to be outside and operating. This will put the health of the crew at risk. Flight crew will mitigate this risk by ensuring that the team has respirators and masks as part of their equipment list and that they will ensure that this equipment is listed on multiple checklists. This action will support the team to continue to operate as the air quality deteriorates. If the conditions become unsafe for any ground operations, the team will RTB or DLI the aircraft to ensure safe flight operations and to ensure the health and safety of the flight crew.

g. *Wildlife in the flight zones:* Local wildlife in proximity to the fire prevents the flight crew from reaching their defined take-off site and/or interfering with the operations while the flight is in process. This prevents the crew from setting up the mission and/or from being unable to safety operate. Flight crew will mitigate this by being aware of local potentially harmful wildlife, carrying safety gear to protect all the ground crew and having safe landing zones to send the aircraft, if the ground team is affected by wildlife and must leave their take-off and landing site.

4. These were developed by the A52 team for a satellite-detected wildland fire in Central Alaska with both large and sUAS responding along with hazardous fire smoke spreading across Alaska and the communities of the Interior. A general hazards ORA that could occur in all use cases under A52 and specific hazards ORA for this use case were developed to accompany the CONOPs. Additionally, a quad chart and a suite of checklists added to the CONOPs and two ORAs.
5. A lUAS would provide higher altitude observations of the detected wildland fire event and be able to sample the fire plume. A tethered sUAS would be flown to provide overview observations of the fire front response and support the Emergency Operations Center (EOC) to determine where ground assets could be sent. A second sUAS would map the fire perimeter and intensity while a third would be sampling the plume generated from the fire as it spreads to support plume forecasting for air quality. The final sUAS would be mapping the landscape ahead of the moving fire to support those in fire spread modeling and mapping the environment below and local cloud cover and/or the plumes.
6. A lUAS is extremely useful to map the full extent of the impact from the fire as it spreads while a suite of sUAS can provide fast response observations and critical intelligence to support response and assessment of the ongoing event. There is not one optimum UAS for this event response. Based on this use case, specific requirements are needed by the operational agencies responsible for the event response, monitoring of the hazard, and mitigating its impact.
   - *Large UAS:* Fixed-wing or VTOL and fixed-wing operations with built in thermal and visible sensors. Where possible, add in fire plume sampling capacity.
   - *Small UAS:* VTOL systems with sustained endurance. Onboard DAA will support EVLOS or BVLOS operations. Coupled sensor systems with minimum visible and thermal. Depending on mission requirements, add in Laser Imaging, Detection, And Ranging (LiDAR), fire plume sampling, and multi-spectral.
7. Similar to the first key finding for this exercise, local incident command structure and fire response protocols must be followed by all organizations involved. Flight crews will need to have knowledge of air traffic in the areas, if TFR is in place, and if so, where. They will need to coordinate with Air Boss. Team will need waivers to get in and out of TFR, if take-off is not in TFR zone. Carry a copy of all teams 107 permissions. Teams should have communications to central operations. Check on any Pilot Reports (PIREPs). Check the weather at flight location and altitudes to be flown. Check operability of in-reach system. Check with incident meteorologist on potential fire spread and plume dispersal. For those organizations developing the next iteration of their event response protocols, adding in the opportunity and assessing the impact that UAS could provide to support the event response then they will have state of the art tools available. These organizations should coordinate on the availability of local to

regional UAS teams to then add them into the event response to benefit the decision-making process.

8. There was no direct reference to C2 in the workshop. Airspace coordination was stated as important given the number of crewed and uncrewed systems. Also, control of the large and sUAS was included in the ORA with corresponding mitigation and discussed with the attendees.
9. Ensuring a safe network of UAS is highlighted in the ORA and having a flight crew be able to mitigate against any bad actors wanting to take control of the aircraft is a consideration in the ORA. In terms of the data produced and products developed, discussions focused on how to make this accessible to all groups in the response. Attendees stated to produce all data in common formats that could be placed on secure servers that could then interface with the relevant software used by each organization.
10. For this use case, a wildland fire seen from satellite data in the Alaskan Interior was selected for the event location. Some of the recommendations from the workshop attendees were as follows:
    - *Operational skills of flight crew:* With such a busy use case, a flight crew should be able to highlight their experience of operating in an event response and around multiple airborne systems, both crewed and uncrewed. This recommendation ensures that the flight crew will then be an asset to the response rather than a hindrance.
    - *Flight teams have incident training:* The flight crew teams should have some level of ICS training. This can be a FEMA 100 and 200 independent study as well as national 700 and 800 course. Also, there is an in-person course, G0191 - ICS/EOC interface. This recommendation ensures all members of the flight crew are aware of the event response protocols and can be an additional asset for the response.
    - *Safety Equipment:* Ensure all flight crew have additional safety equipment as they could come into close contact with wildland fire ash and gases and would need mitigation devices (air filters with masks) to continue to operate. Also, crews should know ongoing hazards so they could evacuate to safe zones if the fire impacted their flight location, including take-off and landing zone. This recommendation ensures the flight crew are safe to operate in and around this hazardous event and can ensure the safety of their crew and not put an extra burden on the other event response teams.
11. For a wildland fire use case, UAS can provide additional capabilities that would be difficult to collect from manned flights. These include:
    - Plume sampling to assist forecasting and air quality assessment.
    - Mapping landscape below cloud deck when manned unable to fly.
    - Vertical profile of atmospheric conditions to support meteorological analysis.
    - Finer-temporal scale actional intelligence to support satellite observations.
    - Large-scale mapping at low altitudes to support asset movement of ground equipment.
    - Real-time classification of fire hotspots and the landscape ahead of the fire, with coupled AI/ Machine Learning (ML).
    - Post-fire analysis to determine if the fire is over and safe for ground crews.

#### 2.5.4.4 Wildland Fire: New Fire in Satellite Data Seminar Lessons Learned Summary:

For this use case, a wildland fire seen from satellite data was selected for the event use case. Lessons learned included:

- Airspace challenges and coordination: it was highlighted by the seminar attendees that ensuring all airspace considerations are in place before flight operations would ensure effective and safe integration of UAS into the event response and the NAS. This would be to ensure COAs in place, permissions for BVLOS operations, Special Government Interests (SGIs) (if needed), and TFRs.
- *Data access in real-time from missions:* Attendees also highlighted the type of data and how it could be accessed from the flight operations to support mission success. Given the location of the wildland fire, the data collected in flight would need to be streamed to the mission ground station and onto the incident command center. For post-flight observations, data needed for rapid assessment would be processed in the field to get the products to the decision-makers.

## 2.6 1/26/2023, Seminar, Wildland Fire: Prescribed Burn, ZOOM, Conducted by UAF

### *2.6.1 Objectives of the Wildland Fire: Prescribed Burn Seminar*

This event of a prescribed burn use case where UAS are supporting the ground crews to monitor the burn event. Three systems are proposed in the use case, each providing a different observation of the event and supporting those responsible for the prescribed burn. The seminar was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case.

### *2.6.2 Planning for and Logistics of the Wildland Fire: Prescribed Burn Seminar*

The seminar was held online via Zoom. Google and Microsoft Team forms were used to have potential attendees sign up and receive the Zoom login data. UAF-ACUASI's network of collaborators and those signed up to the Interest User group were used to showcase the seminar as well as the wider A52 teams' connections and UAS network. 48 people signed up and 31 attended the seminar.

### *2.6.3 Wildland Fire: Prescribed Burn Seminar Execution*

The seminar was one hour long, and attendees followed a slide presentation by Professor Webley from UAF-ACUASI. The attendees also completed a general knowledge survey on their current capabilities with UAS as applied to this use case.

### *2.6.4 Lessons Learned from the Wildland Fire: Prescribed Burn Seminar, Including Responses to Research Questions*

#### 2.6.4.1 Wildland Fire: Prescribed Burn Seminar Key findings:

1. Ensuring that the teams were all aware of the airspace environment and involved in all daily briefings limits the impact of a lack of communication where a flight team might be a hindrance to operations.
2. The team should carry a copy of all teams' 107 permissions.
3. Communication channels: What are the communication channels being used? Where are all other manned/crewed systems supporting the response? It is important to ensure no cross communications occur between teams and all follow ICS procedures.

4. The response will be a complex event and the team will need to show that they can operate safely in this type of operation.

#### 2.6.4.2 Wildland Fire: Prescribed Burn Seminar Recommendations:

For this use case, a prescribed burn in Central Alaska was used as the case for the seminar. A couple of recommendations were proposed by the seminar attendees:

- *Knowledge of downwind air quality:* For events like this prescribed burn, the impact from the hazardous event could extend downwind from the original location. The airborne particulates from the prescribed burn could travel away from the burn site and toward surrounding infrastructure and population centers. Therefore, UAS could provide rapid assessment of air quality at pop-up locations when needed and to provide the observations and data for decision-makers to determine if the air is safe for all members of the community.
- *Mapping of the local landscape from multi-spectral data:* UAS can have multi-spectral sensors included as part of their payload along with the traditional visible and thermal sensors. This multi-spectral data can support the decision-makers to assess the area to be burned and if it is safe to start the prescribed burn. Analysis of this multi-spectral data can information on the vegetation type and surrounding flora that if the burn were to continue could cause the prescribed burn to accelerate into a major hazardous event and extend beyond the containment of the ground teams.

#### 2.6.4.3 Wildland Fire: Prescribed Burn Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. This event of a prescribed burn use case where UAS are supporting the ground crews to monitor the burn event. Three systems are proposed in the use case, each providing a different observation of the event and supporting those responsible for the prescribed burn.
   - *Real-time Situational Awareness:* This is to provide visible and thermal feeds of the ongoing activity. This will support ground teams responding to the prescribed burn and where to place ground assets to monitor the ongoing event. It was also highlighted that drones/UAS can be used to look for hotspots left from the fire front.
   - *Post-flight Mapping:* These would be generated post-flights but during the ongoing monitoring of the burn. Products would include orthorectified imagery and composite maps (both visible and thermal). Consideration is required for the dissemination of this data including all metadata to ensure it can be visualized by all entities in the response, whether from federal, state, local, academia, or private sector.
   - *Post-mission 3D modeling*: Using SfM processing on visual and thermal images produces detailed 3D landscape models. This is especially helpful in areas below cloud cover, which generally prevents mapping by satellite or other crewed systems. Coupled visible and thermal 3D model data provides added intelligence to the local population and infrastructure.
2. Communication is key. Ensuring that the teams were all aware of the airspace environment and involved in all daily briefings limits the impact of a lack of communication where a flight team might be a hindrance to operations. The team should carry a copy of all teams' 107 permissions. Communication channels: What are the communication channels being used? Where are all other manned/crewed systems supporting the response? Ensure no cross

communications between teams and all follow ICS procedures. The response will be a complex event and the team will need to show that they can operate safely in this type of operation.

3. For this use case, the A52 team produced a set of common risks for UAS operations as well as specific risks with action and mitigation plans for a prescribed burn. No new risk was brought up by the seminar attendees.
4. These were developed by the A52 team for a prescribed burnfire in Central Alaska with both large and small UAS responding along with hazardous fire smoke spreading across Alaska and the communities of the Interior. A general hazards ORA that could occur in all use cases under A52 and specific hazards ORA for this use case were developed to accompany the CONOPs. Additionally, a quad chart and a suite of checklists added to the CONOPs and two ORAs. One attendee brought up the need to include an air quality sensor and a Visible And Near Infrared (VNIR) sensor to collect observations during the mission response to the prescribed burn.
5. A lUAS would provide higher altitude observations of the prescribed burn event and be able to sample the fire plume. A small tethered UAS would be flown to provide overview observations of the prescribed burn and support the EOC in determining where ground assets could be sent. A second sUAS would map the fire perimeter and provide ignition and retardant materials and equipment to start and end the prescribed burn.
6. A lUAS is extremely useful to map the full extent of the impact from the fire as it spreads while a suite of sUAS can provide fast response observations and critical intelligence to support response and assessment of the ongoing event. There is not one optimum UAS for this event response. Based on this use case, specific requirements are needed by the operational agencies responsible for the event response, monitoring of the hazard, and mitigating its impact.

   *Additional Small UAS:* VTOL systems with sustained endurance. Onboard DAA will support extended visual line of sight or BVLOS operations. Coupled sensor systems with minimum visible and thermal. Depending on mission requirements, add in multi-spectral and air quality/sampling.

7. For this use case, organizations wanting to integrate UAS into the event response must follow local incident command structure. Flight crews will carry a copy of all teams' 107 permissions. Teams should have communications to central operations. Check on any PIREPS. Check the weather at the flight location and altitudes to be flown. Check with incident meteorologist on potential fire spread and prescribed burn dispersal.
8. There was no direct reference to C2 in the seminar. Airspace coordination, especially downwind of the prescribed burn was deemed important given the potential impact on local air quality as the ashes disperse from the burned landscape.
9. Ensuring a safe network of UAS is highlighted in the ORA and having flight crews to mitigate against any bad actors wanting to take control of the aircraft is a consideration in the ORA. For this use case, there could be three UAS in the airspace at one time, each flight crew ensuring safe operations and knowledge of the location of all other aircraft and the surrounding airspace. Therefore, ensuring that there are no issues between the three ground stations and no potential for bad actors to impact the flights of any one of the crews.
10. For this use case, a prescribed burn in Central Alaska was used as the case for the seminar. A couple of recommendations were proposed by the seminar attendees:

- *Knowledge of downwind air quality:* For events like this prescribed burn, the impact from the hazardous event could extend downwind from the original location. The airborne particulates from the prescribed burn could travel away from the burn site and toward surrounding infrastructure and population centers. Therefore, UAS could provide rapid assessment of air quality at pop-up locations when needed and provide observations and data for decision-makers to determine if the air is safe for all members of the community.
- *Mapping of the local landscape from multi-spectral data:* UAS can have multi-spectral sensors included as part of their payload along with the traditional visible and thermal sensors. This multi-spectral data can support the decision-makers in assessing the area to be burned and if it is safe to start the prescribed burn. Analysis of this multi-spectral data can provide information on the vegetation type and surrounding flora that if the burn was to continue could cause the prescribed burn to accelerate into a major hazardous event and extend beyond the containment of the ground teams.

11. For a prescribed burn use case, UAS can provide additional capabilities that would be difficult to collect from manned flights. These include:
    - Air quality sampling to assist in forecasting and a community safety assessment.
    - Multi-spectral mapping landscape below cloud deck when manned unable to fly.
    - Finer-temporal scale actional intelligence to support satellite observations.
    - Ignition of the prescribed burn area to mitigate placing ground crews at risk.
    - Placement of retardant on burned areas to effectively end the prescribed burn.
    - Post-fire analysis to determine if the fire is over and safe for ground teams.

#### 2.6.4.4 Wildland Fire: Prescribed Burn Seminar Lessons Learned Summary:

For this use case, organizations wanting to integrate UAS into the event response and the NAS will need to follow local incident command structure. Flight crews will carry a copy of all teams' 107 permissions. Teams should have communications with central operations. Check on any PIREPS. Check the weather at flight location and altitudes to be flown. Check with incident meteorologist on potential fire spread and prescribed burn dispersal.

## 2.7 1/30/2023, Seminar, Oil Spill, ZOOM, Conducted by UAF

### *2.7.1 Objectives of the Oil Spill Seminar*

This is an oil spill use case from an oil terminal in Alaska that impacts the surrounding land surfaces and spreads across the Bay. There is also a need to map the impact of the event that led to the spill at the terminal itself. The seminar was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case.

### *2.7.2 Planning for and Logistics of the Oil Spill Seminar*

The seminar was held online via Zoom. Google and Microsoft Teams forms were used to have potential attendees sign up and receive the Zoom login data. UAF-ACUASI’s network of collaborators and those signed up to the Interest User group were used to showcase the seminar as well as the wider A52 teams’ connections and UAS network. 64 people signed up and 44 attended the seminar.

### 2.7.3 Oil Spill Seminar Execution

The seminar was one hour long, and attendees followed a slide presentation by Professor Webley from UAF-ACUASI. The attendees completed a Mentimeter survey that collected information as applied to this use case. For the purpose of providing an accurate estimate of capabilities, the survey only collected responses based on the organization type and position type, not personally identifiable information.

### 2.7.4 Lessons Learned from the Oil Spill Seminar, Including Responses to Research Questions

#### 2.7.4.1 Oil Spill Seminar Key findings:

1. There is no one optimum UAS to support all aspects of this oil spill use case and provide all necessary observations to support the hazard assessment and event response. For this use case, there are different roles that a large or a sUAS provides to support the decision-making process. A lUAS with integrated thermal and visible cameras provides observational data on the full extent of the event. sUAS provide several benefits for this use case. They can, through thermal/visible/LiDAR sensors, support mapping of the damage to the terminal infrastructure from the initial spill event, map the spill extent on land and separately on water, provide herder/burner tools for spill spread mitigation, and provide low-altitude airborne observations of all assets in the event response.
2. Data access is important and a UAS can provide rapid observations of an ongoing event. Access to this data as fast as possible while ensuring integrity and accuracy will be an important component of successfully integrated UAS in event response.

#### 2.7.4.2 Oil Spill Seminar Recommendations:

- All response organizations need to be aware of UAS teams in the vicinity. During an event response, there may be a need to increase the number of UAS platforms to collect data on the spill, provide retardant to mitigate the spill, support SAR, and map the landscape to ensure no further spread. Therefore, knowledge of all available UAS assets is important along with available equipment so that the State Emergency Operations Center (SEOC) or lead organization can call upon these teams in time of need.
- Flight crews show evidence of past event response, including spill response. This event response will have a lot of moving parts. There will be several UAS operations in the surrounding airspace, along with crewed airborne systems and ground/oceanic response teams with their oil spill mitigation equipment. Any flight crew supporting these operations should have experience in operating in active and multi-aircraft responses. This will show that they can respond to potential risks and ensure safe flight operations.
- Flight crews should be aware of all wildlife sites and cultural heritage sites. For this use case, and for others in areas with significant wildlife including protected sites, and with cultural heritage sites in the vicinity, then all flight crews should know the location of wildlife sites of significance as well as heritage sites not to be disturbed. Recommendations would be for the flight crews to have, where appropriate, maps of these sites and if needed direct communications with a local wildlife expert or local cultural heritage expert to determine the inaccessible sites and to ensure safe flight operations.

#### 2.7.4.3 Oil Spill Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. Below are the important roles that UAS provide for this oil spill event:
   - *Data streaming to SEOC:* The seminar attendees spoke about the different ways that the data from the UAS could and should be streamed off the aircraft and to the SEOC and lead organization for the event response. Planning is required on how the thermal and visible data is accessed by those in the incident command and decision-making team, when the UAS may be considerable distances from the EOC or incident command center.
   - *Raw versus processed data:* Discussions were held on what types of data would be available from the UAS during flight or in near real-time as soon as it lands. Follow-on post-mission data could be processed in the field and be made available to the decision-makers rapidly, while additional higher precision data can be produced once the flight crews return from the field. Decisions need to be made on what is provided directly from the aircraft, what is provided to the incident command promptly post flight, and what observations can wait until the flight crew returns from the missions.
2. This use case would be under a full ICS with a SEOC. Communication between the flight crews and the Air Boss/lead for air operations at the SEOC would be essential. All flight crews should know about all airborne operations so they are aware of any other crewed or uncrewed systems that could come into their airspace. Given that there would be multiple UAS flight crews along with other airborne assets as well as ground teams, then to minimize any issues all UAS crews should have comprehensive flight checklists, all permits in place for defined flight patterns, and communicate with central operations before and after a flight.
3. A general ORA for those risks that could impact all use cases under A52 and a specific ORA for this use case are coupled to the oil spill event response. Several specific risks were highlighted by the attendees at the work:
   - *Flight patterns of all airborne assets:* Many crewed and uncrewed systems will be airborne during the response. Therefore, any UAS teams will need to be able to track all other airborne assets while always providing details on the flight patterns and location to the Air Boss and those managing the crewed air assets. A lack of reporting information on the UAS flight and its location could lead to issues of close interactions between crewed and uncrewed assets. UAS teams would need to have well-trained crews and DLI or RTB operations prepared if required during their missions.
   - *Wildlife in the vicinity of operations prevents flight:* Local wildlife moves into the operational footprint of the pre-defined flights. This wildlife may be on the ground or airborne. The wildlife may attack the aircraft or put the crew and operations at risk. If the aircraft is impacted, then it may put the crew, the operation, and other response assets in the vicinity at risk. This results in unsafe flight operations in the NAS with the potential for fly away aircraft and further risk to the response. Flight crew will mitigate this by (1) having knowledge of the local wildlife and its habits; (2) having knowledge of local sites for protected habitats including but not limited to haul outs; and (3) being in communication with wildlife experts to know when it is safe to be around protected locations and when the crew should RTL. This action ensures that the crew continues safe

operations and mitigates the potential of disturbing the wildlife, impacting the operations, and putting both wildlife and flight operations at risk.

- *Drone operations put local wildlife at risk:* UAS can be noisy and in their hover and flight modes produce significant dB's that scare and harass the local wildlife. Flight routes are planned to map the oil spill and hazardous environments and do not take into consideration the local wildlife, especially those in protected sites. This results in wildlife being disturbed and put at risk as well as breaching NOAA and protected site policies on proximity to wildlife. Flight crew will mitigate this by (1) working with local biologists to understand locations of protected sites and their habits; (2) working with operational response to define flight routes that support the event analysis while ensuring safe flight operations and minimal wildlife impact. This action ensures safe flight operations, continued mapping of the ongoing hazard, and undisturbed local wildlife.

4. Attendees at the seminar noted that there is a need to know where all available Part 107 pilots are to respond. Also, there is a need to know where all the resources used in the response are, therefore the UAS crews are aware of other crewed aircraft and all ground response teams.
5. A lUAS would provide higher altitude observations of the oil spill's extent to the local region as well as the potentially wider spread of the oil. A sUAS would be used to map the spill location and impact of the event to the terminal, where another would be used to map the extent of the spill on the oceanic environment and ignite any oil on the water surface and use a retardant to put it out. Attendees at the seminar noted that drone pilots should be integrated into the decision support and ICS.
6. There is no one optimum UAS to support all aspects of this oil spill use case and provide all necessary observations to support the hazard assessment and event response. For this use case, there are different roles that a large or a sUAS provides to support the decision-making process. A lUAS with integrated thermal and visible cameras provides observational data on the full extent of the event. sUAS provide several benefits for this use case. They can, through thermal/visible/LiDAR sensors, support mapping of the damage to the terminal infrastructure from the initial spill event, map the spill extent on land and separately on water, provide herder/burner tools for spill spread mitigation, and low-altitude airborne observations of all assets in the event response. Data access is important and a UAS can provide rapid observations of an ongoing event. Access to this data as fast as possible while ensuring integrity and accuracy will be an important component of successfully integrated UAS in event response.
7. For this use case, response organizations should know all available UAS assets that can support the event response and develop plans of how these systems can be integrated safely and successfully. Coordination between all those agencies responsible for the event should been done ahead of the need and a list of all UAS assets be available to determine the missions that they could perform and continue to operate safely in the NAS.
8. There was no direct reference to C2 links in the seminar. Flight route coordination was stated as important given the number of potential crewed and uncrewed systems.
9. In terms of the data produced and products developed, discussions focused on what would be available as raw data in near real time and what would be post processed. Additionally, one attendee spoke about how AI/ML can be used in event response. The cyber-security and infrastructure needed to safely use such tools in local, state, and federal response events needs further work.

10. For this case, an oil spill from a terminal in Valdez with a spill spreading across landscape and oceanic environment was explored. Below are several recommendations from the attendees' response to this use case:
    - All response organizations should be aware of UAS teams in the vicinity. During an event response, there may be a need to increase the number of UAS platforms to collect data on the spill, provide retardant to mitigate the spill, support SAR, and map the landscape to ensure no further spread. Therefore, knowledge of all available UAS assets is important along with available equipment so that the SEOC or lead organization can call upon these teams in time of need.
    - Flight crews show evidence of past event response, including spill response. This event response will have a lot of moving parts. There will be several UAS operations in the surrounding airspace, along with crewed airborne systems and ground/oceanic response teams with their oil spill mitigation equipment. Any flight crew supporting these operations should have experience in operating in active and multi-aircraft responses. This will show that they can respond to potential risks and ensure safe flight operations.
    - Flight crews should be aware of all wildlife sites and cultural heritage sites. For this use case, and for others in areas with significant wildlife including protected sites, and with cultural heritage sites in the vicinity, all flight crews should know the location of wildlife sites of significance as well as heritage sites not to be disturbed. Recommendations would be for the flight crews to have, where appropriate, maps of these sites and if needed direct communications with a local wildlife expert or local cultural heritage expert to determine the inaccessible sites and to ensure safe flight operations.
11. For an oil spill event use case in this CONOPs, there are specific components of the hazardous event where UAS are best suited as the data collection approach that minimizes risks to ground crew and optimizes other assets:
    - Early-on situational awareness of the oil spread.
    - Real-time data to help SEOC send assets to appropriate site.
    - Real-time monitor, via tethered drone, of all other operations to optimize response.
    - Access to hard-to-reach locations, like small coves, to perform Shoreline Cleanup And Assessment Technique (SCAT) surveys.
    - Proximal observations of impact of oil spread on wildlife and understanding impact that UAS might have on local habitat.
    - AI/ML on-board UAS to provide real-time feed of oil expanse.
    - Ignition of oil via herder-burner approach that limits risk to manned systems.

#### 2.7.4.4 Oil Spill Seminar Lessons Learned Summary:

This use case would be under a full incident command structure with a SEOC. Communication between the flight crews and the lead for air operations at the SEOC would be essential. All flight crews should know about all airborne operations so they are aware of any other crewed or uncrewed systems that could come into their airspace. Given that there would be multiple UAS flight crews along with other airborne assets as well as ground teams, then to minimize any issues all UAS crews should have comprehensive flight checklists, all permits in place for defined flight patterns, and communicate with central operations before and after a flight.

## 2.8 1/31/2023, Seminar, Earthquake with Tsunami, ZOOM, Conducted by UAF

### *2.8.1 Objectives of the Earthquake with Tsunami Seminar*

This use case is a combination of a major earthquake in South Central Alaska that causes a tsunami warning and then impacts a smaller community in the region. The seminar was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case.

### *2.8.2 Planning for and Logistics of the Earthquake with Tsunami Seminar*

The seminar was held online via Zoom. Google and Microsoft Teams forms were used to have potential attendees sign up and receive the Zoom login data. UAF-ACUASI's network of collaborators and those signed up to the Interest User group were used to showcase the seminar as well as the wider A52 teams' connections and UAS network. 48 people signed up and 30 attended the seminar.

### *2.8.3 Earthquake with Tsunami Seminar Execution*

The seminar was one hour long, and attendees followed a slide presentation by Professor Webley from UAF-ACUASI. Additionally, all attendees were asked to complete a Mentimeter survey to record relevant knowledge and capabilities regarding the use of UAS in this specific use case. The survey only collected information about the organization and position type of the attendees—no personally identifiable information was recorded.

### *2.8.4 Lessons Learned from the Earthquake with Tsunami Seminar, Including Responses to Research Questions*

#### 2.8.4.1 Earthquake with Tsunami Seminar Key findings:

For an earthquake with tsunami use case, UAS can provide additional capabilities that would be difficult to collect from manned flights. These include:

- Long-term high-altitude observations of the full extent of the events;
- Continued night-time operations when manned systems are unable to operate to provide overnight derived products for ground-team allocation;
- Rapid response events with the ability to switch out sensors for situational awareness;
- Access to at-risk locations to map landslides that prevent access to infrastructure;
- Proximal Precise mapping of buildings at risk to determine if safe to access;
- Low altitude thermal mapping of infrastructure supports ground asset allocation and SAR;
- Provide preparedness capability to reach at-risk landslide/avalanche areas that might be instigated by earthquake activity before the event occurs;
- Sampling of potential gas leaks without putting ground crews or manned aircraft at risk.

#### 2.8.4.2 Earthquake with Tsunami Seminar Recommendations:

- *Know the available UAS resources in the region:* While the event was written as hitting the City of Seward, the region has other population centers like Valdez that could provide UAS support if required. There are other UAS owners and operators across South Central Alaska so being able to access these groups in times of crisis would be helpful. Work would be needed to know who a safe and effective operator is and would be an asset and not a hindrance to the response.
- *Run test cases and exercises so ready to respond during event:* There are event response exercises that happen, like AlaskEx, and others in the state where plans can be developed to integrate UAS/drones in the events and assess the effectiveness to support ground responses. Additionally, talking to statewide groups responsible for earthquake and tsunami response regularly would help the UAS community understand how the event response organizations would use these innovative systems.

#### 2.8.4.3 Earthquake with Tsunami Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. This use case is a combination of a major earthquake in South Central Alaska that causes a Tsunami warning and then impacts a smaller community in the region. These coupled hazards lead to several subset uses for UAS to support the response of the overall use case. Both large and sUAS would be used during the event.
2. The focus of the seminar was the earthquake and tsunami use case. It was an online event, so all attendees communicated through Zoom and shared their input to the facilitator. The main point brought up by the attendees was the timing of the different flights and the most important data to collect for SAR and situational awareness.
3. A general ORA for those risks that could impact all use cases under A52 and a specific ORA for this use case are coupled to the earthquake and tsunami event response. Several specific risks were highlighted by the attendees at the work:
    - *Large UAS airport inaccessible due to earthquake hazard:* The original earthquake is significant and puts the airport, to be used for the lUAS operations, as unsafe for flight access. This results in the lUAS being unable to take off and complete the high-altitude flight operations to provide data to assess the full extent of the earthquake and tsunami damage. The lUAS flight crew will mitigate this by including additional airport locations as part of their site assessment so that they can still access the airspace needed to provide the operational response teams with the data that they require. Also, if the airport becomes inaccessible during the missions, then the flight crew will use its safety protocols to ensure safe operations of the lUAS in the NAS. These actions will ensure the flights can be completed to provide the observations needed and to ensure no additional risks to safe lUAS flights in the NAS.
    - *UAS with event-specific sensor, SAR, and communications for ground teams:* The attendees noted a specific UAS should be assigned to support SAR teams and also provide an airborne communications platform, as the earthquake could have caused the local ground communications to fail. The lesson learned here is to have available stand-by UAS ready for special cases and specific needs to support the response. This would mean that the organization responsible for the response would need a fleet of aircraft

and operators with experience and ability to determine the likely cases where a UAS would be an asset to the event response.

4. These were developed by the A52 team for a large earthquake centered on Anchorage, Alaska, along with a tsunami event that impacted the City of Seward. This was developed based on the 1964 Good Friday earthquake and Tsunami along with the 2018 November Earthquake in Anchorage. A general hazards ORA that could occur in all use cases under A52 and specific hazards ORA for this use case were developed to accompany the CONOPs. Additionally, a quad chart and a suite of checklists were added to the CONOPs and two ORAs.
5. A lUAS would provide higher altitude observations of the earthquake's impact to the local region as well as the wider tsunami inundation that extends beyond the community to be mapped by the sUAS flights. A sUAS would be flown to support the assessment of a bridge collapse while a second sUAS team will support the event response to evaluate the impact of the tsunami to a local smaller community.
6. There is no one optimum UAS to support all aspects of this earthquake with tsunami use case and provide all necessary observations to support the hazard assessment and event response. For this use case, there are different roles that a large or sUAS provides to support the decision-making process. A lUAS with integrated thermal and visible cameras provides observational data on the full extent of the event. sUAS provide several benefits for this use case. They can, through thermal/visible/LiDAR sensors, support mapping of the damage to the local infrastructure from the initial large earthquake, tsunami wave(s), and earthquake aftershocks. sUAS can also provide observations on local landslides, both as preparedness tools and post-event analysis, and depending on the time of year on avalanche potential and pre-event assessment. UAS can have two roles: one as rapid response situational awareness tool that can get observations on the event impact before any ground crews need to be placed and before other airborne assets can be deployed; the second role is to provide precise data and observations of the hazards and their impact for infrastructure assessment and after-action review of the event impact. This secondary role requires more precise data and can be collected by a UAS that operates around the other ground and air response teams.
7. For this use case, organizations who want to integrate UAS into the event response and the NAS will need to follow local, state, and regional incident command structures. It was stated by attendees that they would be local UAS operators that the response organization could access, such as the City of Valdez. It was also noted, at the time in 2023, that Anchorage Fire did not have a drone program so they may need UAS to support them for event response and those systems come from another organization responding to the event.
8. There was no direct reference to C2 links in the seminar. Airspace coordination was stated as important given the number of potential crewed and uncrewed systems. Also, control of the large and sUAS was included in the ORA with corresponding mitigation.
9. Ensuring a safe network of UAS is highlighted in the ORA and having a flight crew be able to mitigate against any bad actors wanting to take control of the aircraft is a consideration in the ORA. Discussion included how to provide real-time videos to incident command and therefore, how would this feed be securely set up so that no bad actors could access the feed as it may have sensitive information that would not be for the public.
10. Attendees highlighted that UAS could provide additional support to the event response, including but not limited to landslide/avalanche susceptibility assessment, and

landslide/avalanche mapping once hazard is evident. Several recommendations from the attendee's response to this use case are given in Section 2.8.4.2

11. For an earthquake with tsunami use case, UAS can provide additional capabilities that would be difficult to collect from manned flights. These include:
    - Long-term high-altitude observations of the full extent of the events.
    - Continued night-time operations when manned systems are unable to operate to provide overnight derived products for ground-team allocation.
    - Rapid response events with the ability to switch out sensors for situational awareness.
    - Access to at-risk locations to map landslides that prevent access to infrastructure.
    - Proximal Precise mapping of buildings at-risk to determine if safe to access.
    - Low altitude thermal mapping of infrastructure supports ground asset allocation and SAR.
    - Provide preparedness capability to reach at-risk landslide/avalanche areas before the event occurs, that might be instigated by earthquake activity.
    - Sampling of potential gas leaks without putting ground crews or manned aircraft at risk.

#### 2.8.4.4 Earthquake with Tsunami Seminar Lessons Learned Summary:

For this use case, organizations who want to integrate UAS into the event response and the NAS will need to follow local, state, and regional incident command structures. It was stated by attendees that they would be local UAS operators that the response organization could access, such as the City of Valdez. It was also noted, at the time in 2023, that Anchorage Fire did not have a drone program and so there may be UAS required to support them for event response and those systems come from another organization responding to the event.

## 2.9 2/22/2023, Workshop/Tabletop, Hurricane/Tornado/Flooding, Huntsville, AL, Conducted by UAH

The scenario for this use case was a significant hurricane (CAT 4) that passes onto land near New Orleans with subsequent tornadoes impacting the landscape and communities, and then post-event extensive flood waters that continue to impact surrounding communities. Also, the lack of cell coverage requires airborne communications to support ground teams.

Missions:

- lUAS provides long-endurance eyes and communications over the impacted area from high altitude.
- sUAS #1 provides a communications hub for ground operations as well as additional EO/thermal video feed of the area from a tethered position and fixed location.
- sUAS #2 with an EO and thermal payload operates close to buildings to support ground SAR [SAR for survivors].
- Campaigns are short, aiming to support ground operations.
- sUAS #3 with an EO and thermal payload focuses on collecting data on at-risk buildings so that ground teams can assess any potential risk of further damage/collapse.
- sUAS #4 has EO and VNIR payload to fly around the flooded areas to assess extent of water flooding, and also to assess the water levels as they recede over time.

Roles:

- lUAS with real-time data to Ground Control Station (GCS) and on to emergency management operations Center is used as airborne surveillance from above the disaster zone.
- Tethered sUAS #1 in the disaster zone is used as eyes and communications on the event from a fixed location and provides a dedicated communications hub over specific channels only for ground operations use.
- sUAS #2 is flown manually and the flight pattern adapts based on the ground team SAR needs; it will take off and land from several locations as the ground team makes requests.
- sUAS #3 is flown to provide data on the at-risk infrastructure within the disaster zone. As with sUAS #2, sUAS #3 will be flown manually with take-off and landing locations as defined by the needs of the ground team.
- sUAS #4 is flown on predetermined routes based on observations that have been analyzed by the ICS and collected by the lUAS. sUAS #4 will fly with VLOS permissions in place and also with capability to adapt flight plans based on needs of the ICS to map the water levels.
    - Evaluate how sUAS missions can respond to lUAS operations and data analysis.
    - Evaluate how local 107 pilots can respond to needs of State and/or City agencies. Evaluate how tethered UAS #1 can provide eyes and communications on events as well as act as a communications hub.

### *2.9.1 Objectives of the Hurricane/Tornado/Flooding Workshop/Tabletop*

The workshop that followed a few months after the introductory seminar was meant to serve as both an informational session to present use cases and UAS technologies as well as a scripted tabletop exercise with participants. The scenario for the tabletop pulled from lessons learned during Hurricane Ian deployments and from previous A28/A52 scenarios with accompanying checklists. The presentation of the operational checklists was intended to elicit feedback from participants leading to a more informed refinement of the checklists.

### *2.9.2 Planning for and Logistics of the Hurricane/Tornado/Flooding Workshop/Tabletop*

UAH hosted the workshop at the university campus in the conference room of the Rotorcraft Systems Engineering and Simulation Center building. In-person and teleconference options were available. Except UAH personnel, all participants joined via Zoom teleconference. Presentations were developed in-house for technology introduction, use cases, and geospatial data products. A detailed overview of checklists developed by the ASSURE partnership in A28/A52 was presented in Excel and PowerPoint format.

### *2.9.3 Hurricane/Tornado/Flooding Workshop/Tabletop Execution*

The morning session was dedicated to an informational session with presentations and directed questions to the audience for input. The afternoon sessions consisted of the tabletop exercise.

### *2.9.4 Hurricane/Tornado/Flooding Workshop/Tabletop Follow-Up Activities, If Applicable*

ASSURE involvement in the CURSE operational exercise with Florida State University in July 2023 was the main follow-up activity from this exercise.

### *2.9.5 Lessons Learned from the Hurricane/Tornado/Flooding Workshop/Tabletop, Including Responses to Research Questions*

#### 2.9.5.1 Hurricane/Tornado/Flooding Workshop/Tabletop Key Findings:

1. Selection of an appropriate sUAS to use in a specific situation must consider all the factors surrounding the situation, e.g., weather, nature of the payload, anticipated flight duration, and skill of the PIC.
2. Because of the fast-moving developments experienced in disaster response, deconfliction between crews poses a particularly vexing challenge.
3. Because it takes time to familiarize a crew with a particular aircraft, it is ill-advised to introduce a new or recently acquired UAS into an operational environment during a disaster response. The crew is unlikely to understand the nuances of the UAS being considered.
4. When operating with DJI aircraft, the operating team may encounter unexpected GEO fencing locks.
5. Equipment malfunctions are more likely to occur during operations in extreme environments.
6. With regards to communications, especially involving diverse teams who may have never previously operated together, simpler is better – fewer channels of communication with clearly defined protocols.
7. When operating with several crews from diverse sources, one cannot expect them to all be familiar with knowledge of applicable regulations that apply to the designated operating area.

#### 2.9.5.2 Hurricane/Tornado/Flooding Workshop/Tabletop Recommendations:

The following checklists were recommended to all participants for use in any similar disaster. Examples of each were reviewed and discussed:

- Site Survey Checklist
- Mission Planning Checklist
- Pre-Deployment Checklist
- Deployment Checklist
- Pre-Flight Checklist
- Post-Flight Checklist
- Post-Mission Checklist

#### 2.9.5.3 Hurricane/Tornado/Flooding Workshop/Tabletop Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. During major natural disasters, there are four key phases for public safety and health efforts: mitigation, preparedness, response, and recovery. UAS can effectively be used in all four phases associated with hurricanes, tornados, and flood events. Example use cases include:
   a. Mitigation:
      i. Weather forecasting
      ii. Climate and environmental research
      iii. Resiliency assessments
      iv. First responder readiness training

b. Preparedness:
    i. Infrastructure inspection
    ii. Resource transportation
    iii. Resource and personnel evaluation
    iv. Response planning
c. Response:
    i. SAR
    ii. Damage assessment
    iii. Reconnaissance
    iv. Medical/Emergency supply delivery
d. Recovery
    i. Post-event infrastructure inspection
    ii. Force protection /Law enforcement
    iii. Environmental resource assessments
    iv. Rehabilitation resource management

2. While the participant list was short for the Hurricane, Tornado, and Flood workshop, the participants were very engaging and represented all levels of public safety. Namely, we had representation from federal agencies (U.S. Geological Survey), State Agencies (ALDOT) and Local agencies (Lake County Ohio).

   *Participants Online:*

   - Scott Mlacher – Lake County UAS Program in Lake County, Ohio since 2014. Composed of police, fire/rescue, and Emergency Management Service
   - Lance Brady – Chief of National Uncrewed Systems office for the United States Geodetic Survey (USGS) since 2008. Falls under the Department Of The Interior (DOI) with a fleet size of 507 remote pilots and 450 aircraft conducting missions in Earth science. Regularly support volcanic monitoring and volcanic eruptions and wildfires.
   - John Darville –ALDOT. Developed a UAS section at the ALDOT in 2016. Over 4,000 flights in 2022 covering the whole state of Alabama. Mostly construction projects but support hurricane and tornado damage assessments working with Alabama EMA. Consisted of 12 different drones and 6 remote pilots.

3. The most challenging common risk was unqualified personnel conducting flight operations in austere environments engaging with multi-agency, multi-jurisdictional, and multi-disciplinary organizations. An unqualified, illegal operator could shut down operations during response efforts and put resources and personnel at risk. Therefore, significant training, qualification standards, and multi-agency collaborative training is very valuable for mitigating that risk.
4. The typical CONOPs for sUAS follow rules that pertain both to Part 107 and beyond Part 107. For instance, during a disaster response mission, Low Altitude Authorization And Notification Capability (LAANC) and Part 107.41 airspace authorization waivers still prove to be an effective process to operate in controlled airspace. It is imperative to maintain a high level of coordination discipline when operating in a TFR area, especially over austere conditions like the aftermath of severe weather. The SGI process has been streamlined and very effective for sUAS operations in support of disaster response.
5. Both multirotor and fixed-wing sUAS have a role to play in hurricane, tornado, and flooding events and the mission sets outlined in Question 1. Tethered systems may also prove beneficial

as communication and network relays or persistent monitoring of an area or asset (i.e., security or risk assessment).

6. There is no shortage of diversity in mission sets, mission requirements, and mission demands during hurricanes, tornados, and flooding events. The devastation is significant. The only commonality of UAS platforms to consider for optimal performance are:
    - Flight Endurance (one hour or greater)
    - Rapid Deployment (easy to deploy and pack up for quick relocation)
    - Safety Redundancies (broadcasting location, geofence, maximum and minimum altitudes and distances from operator)
    - Ruggedized Design (must be able to sustain safe operations in the disaster zone)

7. The term "common operating picture" comes to mind. Fully integrated traffic management with manned and unmanned teaming, as well as ground assets, is important. Additionally, reducing redundancies for data collection missions while maximizing "eyes on scene" is important. It is always a good idea to check the same area multiple times in case something is missed but this must be balanced with effective use of resources. A Geographic Information System (GIS) with aviation, ground, and maritime assets helps incident command make effective decisions.
8. Encryption is an important consideration for C2 but not at the expense of effective communication. The majority of UAS deployed during disaster response are COTS systems that use fairly basic security measures, though there are some exceptions. Encrypting transmission is important, but the security of hardware is more important. For instance, the transceiver on the aircraft and GCS, as well as the software/firmware used for both devices, are more important to secure than the transmission broadcast itself.
9. The personally identifiable information and sensitive data from disaster response efforts can have devastating consequences if taken advantage of or not properly handled.
10. Recommendations to incident command and public safety leadership on how to safely deploy UAS assets, what kind of data can be collected, the data processing requirements needed to create actionable data products, and how to properly integrate UAS with other emergency management resources is an important step in developing the requirements, technical standards, and policies/procedures to enable the next generation first responder.
11. The scale of capability reduces as image resolution increases. This is true for both spatial and temporal resolution of data. Satellites provide the largest geographic scale but are often limited in spatial and temporal resolution. Temporal resolution for satellites is dictated by the orbital period. Manned aircraft further reduces scale and can be deployed to locations as needed, increasing spatial and temporal resolution. However, manned aviation requires infrastructure such as fuel depots of specialty fuel, assigned landing sites, location broadcasting, and communication networks. As the scale further reduces, UAS can fill in for lower altitudes and smaller geographic extent. Although some UAS can have significant endurance and areal coverage, UAS, in general, are deployed with ground team resources and provide a wide range of capabilities. For instance, the same UAS can be used to perform damage assessment of large areas, reconnaissance missions for personnel safety, SAR, and communications relay.

#### 2.9.5.4 Hurricane/Tornado/Flooding Workshop/Tabletop Lessons Learned Summary:

The discussion at this workshop was driven by directed questions to the audience and the UAH hosts. The diversity of the participants, while small in size, led to beneficial feedback from a wide range of operational contexts. Local, state, and federal government UAS operators were represented at this workshop, where they provided valuable feedback based on their very specific use cases.

## 2.10 3/24/2023, Drill, Flood Response, Starksboro, VT, Conducted by UVM

sUAS flight operations by the University Of Vermont (UVM) Spatial Analysis Laboratory were conducted on March 24, 2023, to evaluate UAS response to flood conditions along Lewis Creek in Starksboro, VT.

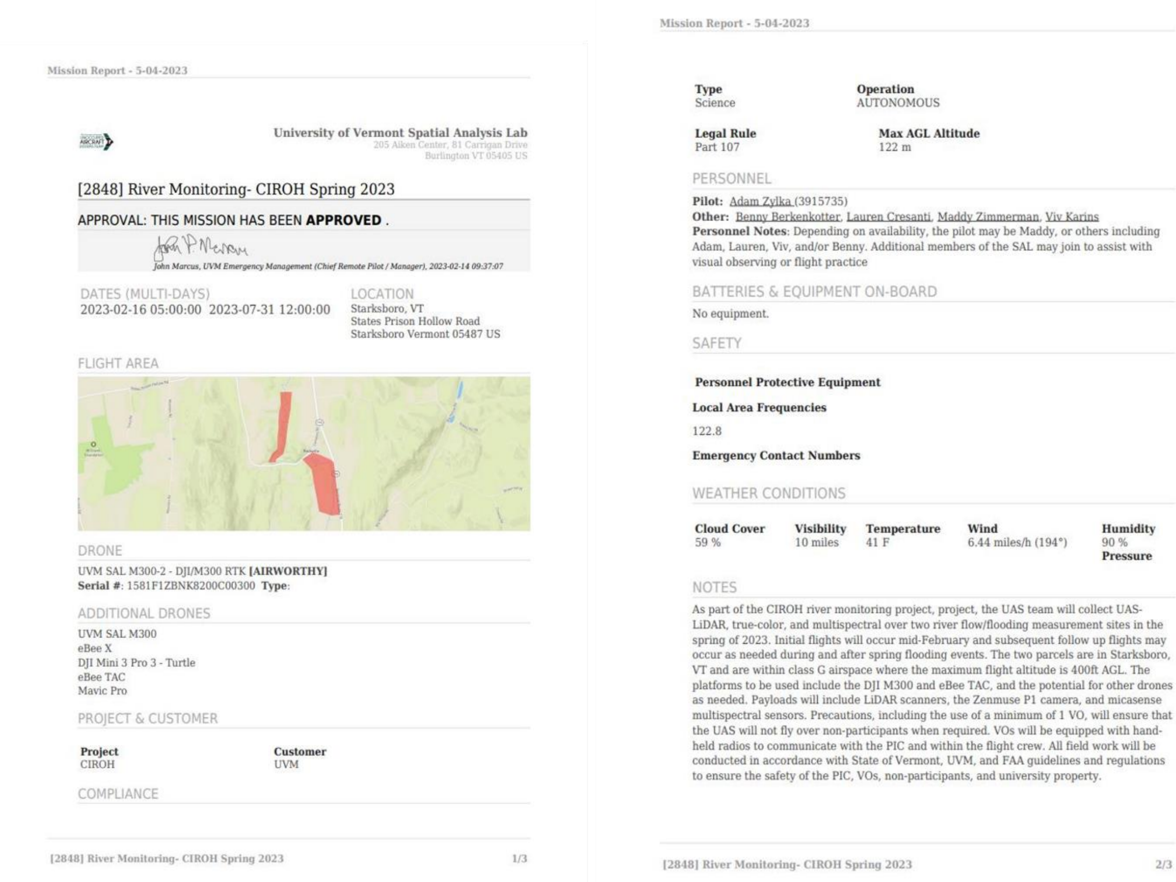
### *2.10.1 Objectives of the Flood Response Drill*

The purpose of this drill was to execute a UAS mapping mission under flood conditions to evaluate the processes, procedures, capabilities, limitations, processing, and dissemination activities. This drill served as an evaluation of the ability to predict and capture high-water flood levels in UAS data, evaluate the usage of flight checklists and UAS platforms and sensors, determine the types of UAS data that are most applicable to determining floodwater extent, and develop a workflow to share and visualize these datasets.

### *2.10.2 Planning for and Logistics of the Flood Response Drill*

Through the spring of 2023, UVM's UAS Team collected data along Lewis Creek in support of additional research objectives related to floodplain monitoring. This location was identified as an area of concern for flood events that may impact multiple properties within the rural community of Starksboro, VT.

In preparation for executing the drill, UVM's research staff selected UAS platforms and sensors for deployment and generated automated flight plans for mapping. An AgEagle (senseFly) eBee X fixed-wing UAS was selected for its ability to carry out wide-scale mapping operations, with a senseFly Duet-T Electro-Optical/Infrared (EO/IR) imagery sensor. A DJI Mavic 3 was selected to capture oblique imagery and video of river conditions at the time of the drill. In advance of executing the drill, the UVM UAS Team received authorizations and approvals for the flight operations from UVM's UAS Working Group, which administers UAS flight operations at the university. This was facilitated through the DroneLogBook compliance management solution. As part of this authorization (Figure 1), the staff documented the regulations under which operations would occur, airspace classification, relevant Common Traffic Advisory Frequency (CTAF)/ Universal Communications (UNICOM) frequency for monitoring communications from manned aviation, and other regulatory and risk mitigation items as appropriate.


Mission Report - 5-04-2023

University of Vermont Spatial Analysis Lab
205 Aiken Center, 81 Carrigan Drive
Burlington VT 05405 US

[2848] River Monitoring- CIROH Spring 2023

APPROVAL: THIS MISSION HAS BEEN **APPROVED** .

*John Marcus, UVM Emergency Management (Chief Remote Pilot / Manager), 2023-02-14 09:37:07*

DATES (MULTI-DAYS)
2023-02-16 05:00:00 2023-07-31 12:00:00

LOCATION
Starksboro, VT
States Prison Hollow Road
Starksboro Vermont 05487 US

FLIGHT AREA

DRONE
UVM SAL M300-2 - DJI/M300 RTK **[AIRWORTHY]**
**Serial #**: 1581F1ZBNK8200C00300 **Type**:

ADDITIONAL DRONES
UVM SAL M300
eBee X
DJI Mini 3 Pro 3 - Turtle
eBee TAC
Mavic Pro

PROJECT & CUSTOMER

**Project**
CIROH

**Customer**
UVM

COMPLIANCE

[2848] River Monitoring- CIROH Spring 2023 1/3

Mission Report - 5-04-2023

**Type**
Science

**Operation**
AUTONOMOUS

**Legal Rule**
Part 107

**Max AGL Altitude**
122 m

PERSONNEL

**Pilot:** Adam Zylka (3915735)
**Other:** Benny Berkenkotter, Lauren Cresanti, Maddy Zimmerman, Viv Karins
**Personnel Notes**: Depending on availability, the pilot may be Maddy, or others including Adam, Lauren, Viv, and/or Benny. Additional members of the SAL may join to assist with visual observing or flight practice

BATTERIES & EQUIPMENT ON-BOARD

No equipment.

SAFETY

**Personnel Protective Equipment**

**Local Area Frequencies**

122.8

**Emergency Contact Numbers**

WEATHER CONDITIONS

| Cloud Cover | Visibility | Temperature | Wind | Humidity |
|---|---|---|---|---|
| 59 % | 10 miles | 41 F | 6.44 miles/h (194°) | 90 % |
| | | | | **Pressure** |

NOTES

As part of the CIROH river monitoring project, project, the UAS team will collect UAS-LiDAR, true-color, and multispectral over two river flow/flooding measurement sites in the spring of 2023. Initial flights will occur mid-February and subsequent follow up flights may occur as needed during and after spring flooding events. The two parcels are in Starksboro, VT and are within class G airspace where the maximum flight altitude is 400ft AGL. The platforms to be used include the DJI M300 and eBee TAC, and the potential for other drones as needed. Payloads will include LiDAR scanners, the Zenmuse P1 camera, and micasense multispectral sensors. Precautions, including the use of a minimum of 1 VO, will ensure that the UAS will not fly over non-participants when required. VOs will be equipped with hand-held radios to communicate with the PIC and within the flight crew. All field work will be conducted in accordance with State of Vermont, UVM, and FAA guidelines and regulations to ensure the safety of the PIC, VOs, non-participants, and university property.

[2848] River Monitoring- CIROH Spring 2023 2/3

Figure 1. Mission authorization request for flood response drill.

Monitoring for possible flood conditions was informed by hydrograph forecasts provided by the NWS Northeast River Forecast Center. **Error! Reference source not found.** displays the observed and predicted water levels in the nearby Winooski River during the week of the drill. Increases in water levels to or near flood stage were anticipated due to the combination of spring rains and snowmelt. The hydrograph forecast provided insight into expectations of peak flow rates and potential action flood stage occurring on March 24, 2023.

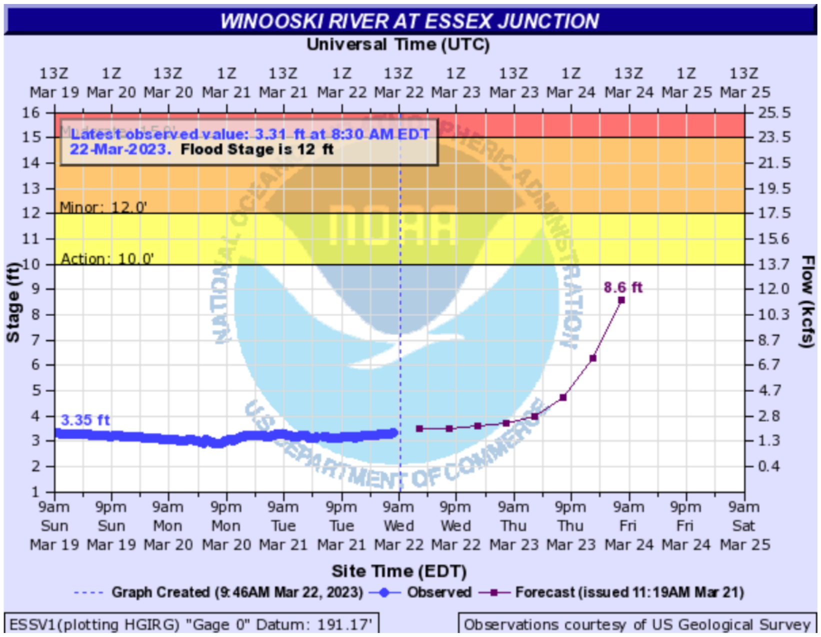


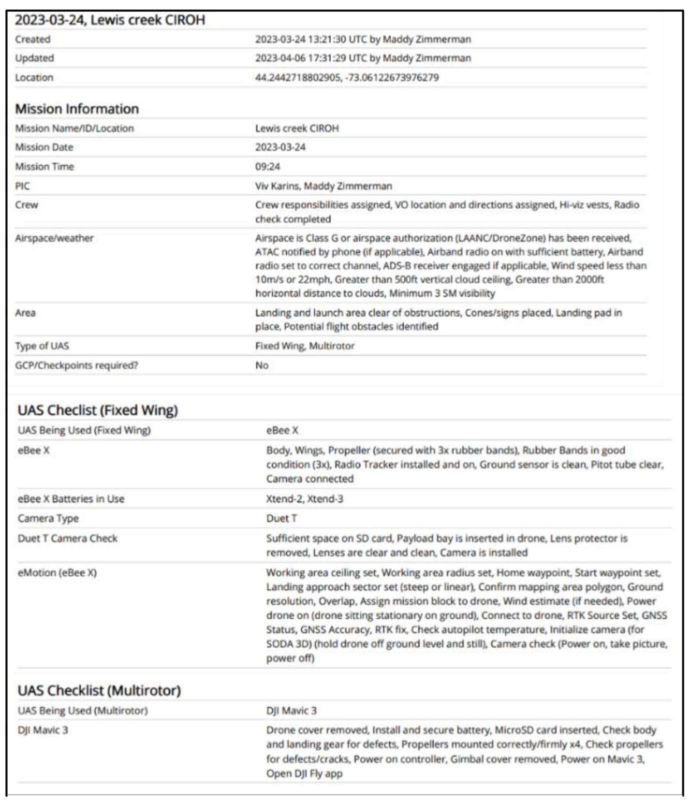

Figure 2. Hydrograph observation and forecast for Winooski River between March 10-25, 2023.

UAS research staff generated a flight plan for the eBee X and Duet T mapping package, displayed in Figure 3. This sensor captures EO/IR imagery and can therefore generate both true-color orthoimagery products and thermal reflectance/temperature maps. However, due to the focal length of the thermal sensor, the overlap parameters of the EO imagery are greater than typical standard practices resulting in increased flight time. The mission area was approximately 125 acres. The basemap and elevation data for the mapping area were cached locally on the ground station laptop to allow for a visual reference of the region should internet connection be unavailable in the field.


Figure 3. eBee X mapping flight plan.

### *2.10.3 Flood Response Drill Execution*

The flood response drill began with extensive pre-flight checks for the site and any hazards, as well as team preparedness through a customized checklist in Fulcrum software. Checks included verification of weather in compliance with Part 107 regulations and platform limitations, identification of potential in-flight obstacles, tasking of roles and locations for PIC and VOs, confirmation that radios were working properly, and planned emergency procedures. Next, custom checklists designed for the designated platforms, sensors, and flight planning software were completed to verify that the systems were properly prepared for flight. The completed checklist information can be seen in Figure 4.



**2023-03-24, Lewis creek CIROH**

| | |
|---|---|
| Created | 2023-03-24 13:21:30 UTC by Maddy Zimmerman |
| Updated | 2023-04-06 17:31:29 UTC by Maddy Zimmerman |
| Location | 44.2442718802905, -73.06122673976279 |

**Mission Information**

| | |
|---|---|
| Mission Name/ID/Location | Lewis creek CIROH |
| Mission Date | 2023-03-24 |
| Mission Time | 09:24 |
| PIC | Viv Karins, Maddy Zimmerman |
| Crew | Crew responsibilities assigned, VO location and directions assigned, Hi-viz vests, Radio check completed |
| Airspace/weather | Airspace is Class G or airspace authorization (LAANC/DroneZone) has been received, ATAC notified by phone (if applicable), Airband radio on with sufficient battery, Airband radio set to correct channel, ADS-B receiver engaged if applicable, Wind speed less than 10m/s or 22mph, Greater than 500ft vertical cloud ceiling, Greater than 2000ft horizontal distance to clouds, Minimum 3 SM visibility |
| Area | Landing and launch area clear of obstructions, Cones/signs placed, Landing pad in place, Potential flight obstacles identified |
| Type of UAS | Fixed Wing, Multirotor |
| GCP/Checkpoints required? | No |

**UAS Checlist (Fixed Wing)**

| | |
|---|---|
| UAS Being Used (Fixed Wing) | eBee X |
| eBee X | Body, Wings, Propeller (secured with 3x rubber bands), Rubber Bands in good condition (3x), Radio Tracker installed and on, Ground sensor is clean, Pitot tube clear, Camera connected |
| eBee X Batteries in Use | Xtend-2, Xtend-3 |
| Camera Type | Duet T |
| Duet T Camera Check | Sufficient space on SD card, Payload bay is inserted in drone, Lens protector is removed, Lenses are clear and clean, Camera is installed |
| eMotion (eBee X) | Working area ceiling set, Working area radius set, Home waypoint, Start waypoint set, Landing approach sector set (steep or linear), Confirm mapping area polygon, Ground resolution, Overlap, Assign mission block to drone, Wind estimate (if needed), Power drone on (drone sitting stationary on ground), Connect to drone, RTK Source Set, GNSS Status, GNSS Accuracy, RTK fix, Check autopilot temperature, Initialize camera (for SODA 3D) (hold drone off ground level and still), Camera check (Power on, take picture, power off) |

**UAS Checklist (Multirotor)**

| | |
|---|---|
| UAS Being Used (Multirotor) | DJI Mavic 3 |
| DJI Mavic 3 | Drone cover removed, Install and secure battery, MicroSD card inserted, Check body and landing gear for defects, Propellers mounted correctly/firmly x4, Check propellers for defects/cracks, Power on controller, Gimbal cover removed, Power on Mavic 3, Open DJI Fly app |

Figure 4. Pre-flight mission checklists for flood response drill.

Once all pre-flight checklists were completed and the PIC was prepared to operate, the DJI Mavic 3 multirotor was deployed near 10:10 Eastern Daylight Time (EDT). The UAS was flown under manual control, with a maximum altitude of 393 feet AGL for the purpose of capturing oblique aerial images and video of the river and to quickly identify any flood conditions on-site in the live video feed. The total flight length was approximately 20 minutes, covering more than 7000 linear feet.

The UAS maximum distance from the PIC was approximately 1500ft horizontally, which allowed for sustained VLOS operation. Flood conditions were not identified by the PIC in real time during this flight using the live camera feed. The PIC captured 29 oblique image sets (JPG + RAW format) and 15 videos (MP4 format), which were copied from the SD card of the UAS to a ground station laptop and manually reviewed in an attempt to rapidly identify potential flooding, in case the mapping flight plans required adjustment.

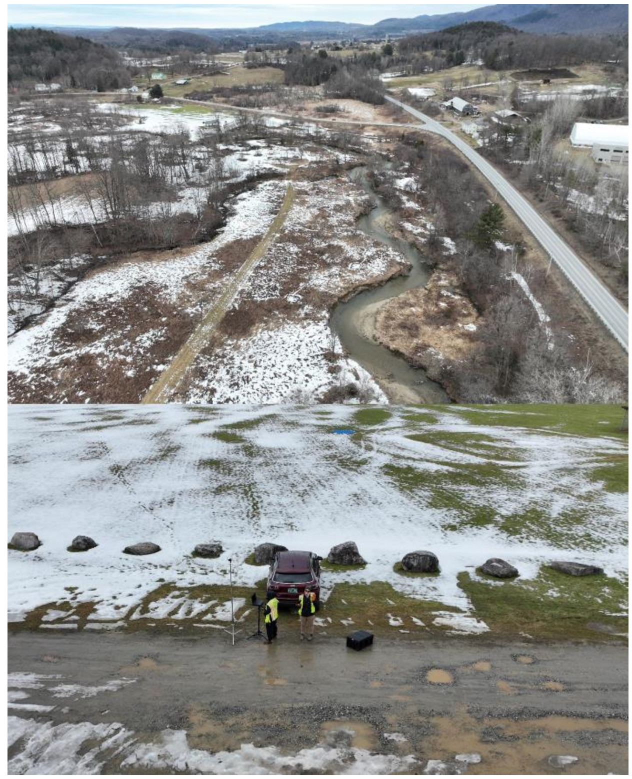


Figure 5. Flood response drill flight operations.

The second flight to occur was EO/IR mapping imagery collection using the senseFly eBee X and Duet-T sensor. In preparation for the mission, the relevant custom pre-flight checklist for the platform and sensor were completed to ensure mission readiness. The flight plan created in preparation for the drill was loaded into senseFly's eMotion software and further adjustments were made to the Start and Home (landing) waypoints, the orientation of the landing trajectory to account for obstacles on site (trees, powerlines, fences), and the prevailing wind speed and direction. Due to the lack of flood conditions identified during the previous multirotor flight, adjustments to the planned mission trajectory were not carried out. A Verizon MiFi hotspot was deployed to provide the ground station laptop with internet connectivity so that the UAS could be connected to the Vermont VECTOR Real-Time Kinematic (RTK) network for increased spatial accuracy. Integration of a UAvionix pingUSB Dual-Band Automatic Dependent Surveillance-Broadcast (ADS-B) Traffic Receiver with the eMotion software allowed the PIC to have additional awareness of possible nearby manned aviation.

Following the launch of the eBee X at 10:33 EDT, the UAS was commanded to loiter on the Start waypoint for 5 minutes to stabilize the IR camera's internal temperature, per the manufacturer's recommendation. Following this period, the PIC commanded the eBee X to begin the mapping mission, consisting of north-south parallel flight lines at or under 400ft AGL. The maximum distance of the UAS from the PIC during this mission was approximately 4000ft horizontal. The PIC was able to retain VLOS throughout the flight due to the height, size, color, and shape profile of the UAS system. The eBee was able to complete only 60% of the planned missions and the PIC commanded the eBee to return Home for landing with approximately 40% of the remaining battery available. The UAS landed and was powered off at 11:01 EDT, for a 28-minute flight time. The images and UAS flight log were copied from the sensor to the ground station laptop immediately following landing before the UAS was prepared for a second flight to complete the mapping mission.

The subsequent eBee X flight began at 11:07 EDT, six minutes after its prior landing. Following launch, it was commanded again to loiter at the Start waypoint for five minutes to allow the IR sensor to stabilize temperature, before the PIC commanded the eBee X to resume the pre-planned mapping mission beginning at the last waypoint. The PIC allowed the eBee X to automatically return to Home for landing after completion of the programmed mission at 11:29 EDT. During the initial linear landing approach, the PIC issued an abort landing command to the UAS at 11:31 EDT due to concerns about obstacles in the landing approach. Adjustments were made and the PIC issued a second linear landing command to the UAS, which was successful. In total, this flight spanned more than 25 minutes. Images and flight logs were copied locally to the ground station computer following completion of this mission. In total, mapping the approximately 125-acre area with a combined EO/IR mapping imagery sensor took more than 53 minutes of flight time. 3D views of the two flight trajectories can be found in Figure 6.


Figure 6. eBee X flight trajectories.

### *2.10.4 Flood Response Drill Follow-Up Activities, If Applicable*

In the hours following completion of the flight operations, the data and flight logs captured by the two UAS platforms were copied to a UVM-hosted server system for shared access. The oblique images and videos were reviewed and organized for sharing purposes, JPG image format was the most efficient for dissemination.

The EO and IR imagery captured with the Duet-T sensor between the two flights totaled 1690 images. These were imported to create a new project in Pix4Dmapper photogrammetry software and processed on a high-powered workstation (12 Central Processing Unit (CPU) cores, 128GB

Random Access Memory (RAM), discrete Graphics Processing Unit (GPU)). The discrete processing phases required to generate true color orthoimagery, a digital surface elevation model, and a thermal reflectance and temperature map exceeded 100 minutes. As a result of the overlapping images, the area of these data products exceeded 200 acres, which was 75 acres more than planned during data collection.

The resulting data products were imported to a new project in ArcGIS Pro for visualization and sharing. These raster layers were published to ArcGIS Online, which took more than 90 minutes to complete. These tile layers were added to an ArcGIS Online group with shared update permissions, allowing any group member to modify the sharing, naming, and display of the layers. The layers were displayed within an ArcGIS Online Web Map, which was used to create an ArcGIS Online Web Mapping Application. This public application can be found at the following URL:

[https://go.uvm.edu/0hbzo](https://go.uvm.edu/0hbzo).

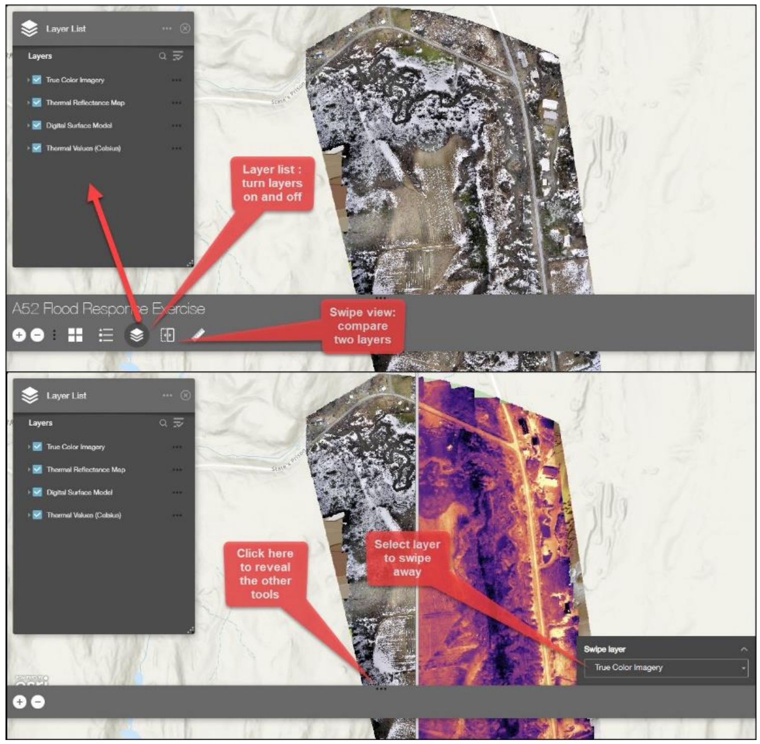



Figure 7. ArcGIS Online Web Mapping Application.

Flight logs from both UAS platforms used during the drill were synchronized to the DroneLogBook log management platform within 48 hours following flight operations.

### *2.10.5 Lessons Learned from the Flood Response Drill, Including Responses to Research Questions*

#### 2.10.5.1 Flood Response Drill Key findings:

1. If available, a small multirotor UAS with a live video capability provides significant and rapid insight into flood conditions and impacted regions, including if there are no flood impacts in the area.
2. Capturing oblique images in RAW-format can be cumbersome and incur large file sizes compared to JPG-format images. RAW file formats are not compatible with all standard image viewing software.
3. Predicting flood conditions based solely on hydrograph forecasts can be challenging, adding difficulty to the task of capturing highwater marks with UAS.
4. Thermal mapping data provides marginal added value in determining the extent of water, particularly in near-freezing outdoor temperatures.
5. The thermal sensor (senseFly Duet-T) used to capture mapping data added inefficiency to the collection of mapping data and was a primary contributor to requiring multiple flights to map the planned 125-acre area.

- Requires narrower lateral distance between adjacent flight lines due to narrow field-of-view, resulting in a greater number of flight lines required than if only true-color imagery was collected.
- The manufacturer recommends best practice of loitering for 5-10+ minutes before beginning mapping data collection to allow for sensor temperature to stabilize.
- Duet-T sensor has increased weight (268g) over equivalent true-color sensor (senseFly SODA at 111g). Manufacturer documentation indicates a 25% decrease in flight time in optimal conditions when comparing the Duet-T and SODA.
- It is anticipated that deployment of the SODA EO sensor would have required only a single flight of less than 40 minutes to complete mapping of the 125-acre mission area.

6. Custom pre-flight checklists tailored to a platform and sensor combination provide operators in stressful environments with a trusted method to avoid human error.
7. Basemaps and elevation data in ground control software should be downloaded or cached for offline usage before deployment. Reliance on reliable internet connectivity during flight operations should be avoided.
8. Capturing mapping imagery with high spatial accuracy using RTK and/or Post-Processing Kinematic (PPK) Global Positioning System (GPS) corrections, when available, can provide more accurate georeferencing of UAS imagery, improving the precision of orthoimagery.
9. Localized processing of orthoimagery may only be scalable with sufficient processing capacity on high-powered workstations.
10. Sharing orthoimagery, elevation, and other raster data through ArcGIS Online provides an effective and reasonably efficient way to disseminate large datasets for public viewing and analysis. Due to the large size of files, this is likely not feasible while mobile or conducting operations.

#### 2.10.5.2 Flood Response Drill Recommendations:

- Utilize a small multirotor UAS with live video capability for initial inspection of flood conditions. Adjust pre-programmed mapping flight plans or generate a new flight plan on the fly based on this rapid feedback about the conditions and impacted regions.
- Capture oblique images in JPG-format only to facilitate rapid sharing and to simplify file management.
- Orthoimagery can be captured, processed, and disseminated via online web mapping applications within hours of deployment. Recommend developing the efficiency of this workflow to minimize processing time, account for varying levels of computing resources available, and to establish best practices for sharing orthoimagery via ArcGIS Online.
- Focus primary orthoimagery data capture around true-color/EO imagery to maximize efficiency in flight operations and data processing. The value of IR data and thermal reflectance/temperature maps did not provide significant insights into the extent of water levels during this drill in near-freezing conditions and increased both the required flight time and processing time.
- Utilize RTK and/or PPK geospatial corrections for mapping imagery, when possible, to allow for best potential pre/post flood data comparisons.

- Prediction and timing of UAS data collection during flood conditions can be challenging. Tasking of UAS resources for flood response should be supported in advance by response personnel familiar with meteorological and hydrological forecasting.

#### 2.10.5.3 Flood Response Drill Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. In this drill, manual flight of a small multirotor UAS platform allowed the pilot to quickly evaluate the area, determine the extent of any flooding, and capture oblique images before beginning an automated flight plan with a fixed-wing to collect mapping data. Using a fixed-wing for mapping allowed greater efficiency and increased battery life compared to mapping with a multirotor over an area spanning hundreds of acres.
2. N/A
3. A common risk when manually operating a UAS platform, as used in this case to collect obliques and assess the area, is the potential for collision with obstacles. The primary obstacles in this area were trees. To mitigate this risk, some UAS platforms are equipped with obstacle avoidance sensors that cause the UAS to break or alert the pilot when in proximity to an obstacle. Utilizing one or more VOs can also help to ensure that the UAS maintains a safe distance from any obstacles, as observers can see the platform from a variety of angles. In addition, maintaining a flight height above trees or other obstacles reduced any concern of collision during this flight.

   Landing a fixed-wing platform, such as the eBee X, presents challenges that require careful planning and real-time decision-making to mitigate the risk of collision, especially when operating in environments surrounded by obstacles like trees. A crucial aspect of this process is the careful selection of the landing location, or home point, which should be an open, flat area free of hazards that could interfere with a safe landing. The approach must be configured to ensure the UAS is flying into the wind, which helps reduce ground speed and allows for a more controlled descent. Utilizing VOs is also important, as they can provide the pilot with real-time feedback on the position of the UAS and any potential hazards in the landing approach. This combination of careful site selection, continuous monitoring, and the ability to abort and retry landings when conditions are not ideal helps mitigate the risk of collision and ensures a safer landing process.

4. N/A
5. Oblique imagery/video collection & live aerial view: small to medium multirotor sUAS with the ability to capture JPG-format imagery, video files, and provide live video stream to the controller.

   True-color orthoimagery collection: dependent on the area impacted by floodwaters. Areas less than 50-100 acres can likely utilize multirotor UAS with dedicated EO imagery sensor for data collection. Areas larger than 100 acres may be better served by a fixed-wing and/or VTOL UAS platform with EO imagery sensor designed for large-area mapping purposes. The fixed-wing and VTOL platforms will provide greater efficiency in mapping imagery collection compared to common multirotor systems, though mapping of large areas can be accomplished through the execution of multiple multirotor missions. Operations Over People (OOP)-compliant UAS would be recommended for mapping flood extent over urban areas.

6. When responding to a disaster such as flooding, it would be ideal to bring multiple UAS platforms, as each platform serves a unique purpose and has specific advantages. During this drill, it was beneficial to have access to both a small quadcopter and a fixed-wing UAS. However, if a response is limited to a singular UAS platform, the optimum UAS would be a multirotor that can provide a real-time video feed to the controller, for situational awareness, and capturing oblique images and videos using manual flight, as well as carrying out an automated mission for mapping purposes.
7. N/A
8. N/A
9. N/A
10. N/A
11. Relatively small-scale hazards are best suited for UAS compared to manned flights. In this case, over 200 acres of data was collected, which was feasible for maintaining line of sight and completing flights in a relatively short time. These factors are situational, and some areas larger than this could be successfully mapped with UAS, but anything larger than a localized response would be better suited to manned flights.

    UAS deployment can provide a rapid and cost-effective way of providing situational awareness of the impacts (or lack of impacts) from flood events, potentially precluding the need for support from manned aviation should a brief flight from a small multirotor UAS indicate that flooding is not impacting the area as anticipated.

#### 2.10.5.4 Flood Response Drill Lessons Learned Summary:

Oblique imagery, oblique videos, and true-color orthoimagery data provided by UAS offer the greatest value in efficiency of collection, analysis, and rapid sharing for flood response efforts. If only a single UAS platform is available, the recommendation is for a multirotor UAS that can capture oblique imagery, video, provide a real-time live video feed to the PIC, and can execute pre-programmed flight plans to capture EO imagery for orthoimagery generation. Further development in best practices for true-color orthoimagery processing and dissemination is required to facilitate standardized and rapid data sharing.

## 2.11 3/29/2023, Seminar, Train Derailment, Burlington, VT and Online, Conducted by UVM

This was the first seminar for planning a mock train derailment response with sUAS technologies. The meeting began with discussing the major logistics to consider. This meeting was hosted by the UVM Spatial Analysis Lab (SAL) Director and UAS Team Lead. In attendance were the UVM Emergency Management Director, Vermont Agency Of Transportation (VTrans) Rail and Aviation Bureau Director, VTrans UAS Program Director, as well as other members of the SAL UAS team including staff, students, and interns. As is the case with all following seminars and workshops, this event was hosted in person on UVM’s campus as well as online through a Microsoft Teams call to allow for flexibility in attendance.

### *2.11.1 Objectives of the Train Derailment Seminar*

For this initial meeting, the primary goal was for UVM to introduce the idea of the functional exercise to potential collaborators and start to receive feedback, ideas and suggestions for the exercise moving forward. This process would involve sharing the vision for the exercise, considering location options and any associated concerns for the area, and discussing other major logistics to work out in the following meetings. It was important to highlight that this would be a collaborative effort, with the input and needs of other organizations and agencies driving the planning process.

### *2.11.2 Planning for and Logistics of the Train Derailment Seminar*

The planning of this first train derailment seminar was conducted weeks in advance. The UVM Team met internally to work out key decisions beforehand, including the goals of the exercise, which collaborators should be included in the initial planning stages, and the meeting objectives, topics, and agenda for the first seminar.

The vision for the train derailment exercise was to bring together major players throughout the state of Vermont to work through challenges that may arise when responding to an emergency using UAS. Emphasis would be placed on a scenario in which multiple agencies are operating UAS at the same time, introducing potential challenges surrounding airspace coordination, communication, and effective data collection. Each seminar could promote valuable conversation and exchange of ideas, with the final exercise putting these plans into place and offering a space for evaluation of the performance and methods for improvement in the future.

In terms of participants, UVM considered who in the state might benefit from being heavily involved in the planning process and hands-on flight experience. Because of their established UAS program and collaboration with UVM in the past, VTrans was identified as a key player to include in the exercise, with hope that this collaboration would strengthen relationships between teams, improve collaboration efforts, share knowledge and expertise, and develop best practices together. Later in the planning process, the intention would be to identify and include additional stakeholders throughout the state of Vermont who would similarly benefit from a mock UAS exercise, such as agencies beginning to develop their own UAS program related to emergency or disaster response.

Leading up to the event, virtual meeting links were sent to seminar participants to join remotely, and an indoor space was booked on UVM's campus for those attending in person. Before this seminar and in preparation for each remaining seminar, the UVM team often carried out internal meetings to continue planning, track progress on tasks, and move event preparation forward. This allowed UVM to discuss small details and work through tasks as the lead for the exercise without taking up too much time during official seminars.

For the first seminar, UVM prepared a PowerPoint presentation to introduce the exercise, share initial thoughts, and kickstart the exercise planning process.

### *2.11.3 Train Derailment Seminar Execution*

During the first seminar, UVM presented information via PowerPoint regarding the exercise goals and key points to begin considering. Throughout the presentation, open discussion was held amongst participants to provide input, questions, concerns, suggestions, ideas, and other valuable insights. Following the presentation, conversations expanded on these topics and any other relevant considerations. A variety of topics were discussed to begin planning logistics of the mock exercise including, but not limited to:

- The vision (**Error! Reference source not found.**) and objectives (Figure 9) for the mock train derailment exercise to provide an overview of why the event was being hosted and the intended outcomes. These outcomes include exercise and flight experience, testing CONOPs, improving collaboration, and integrating UAS into emergency planning in the state.

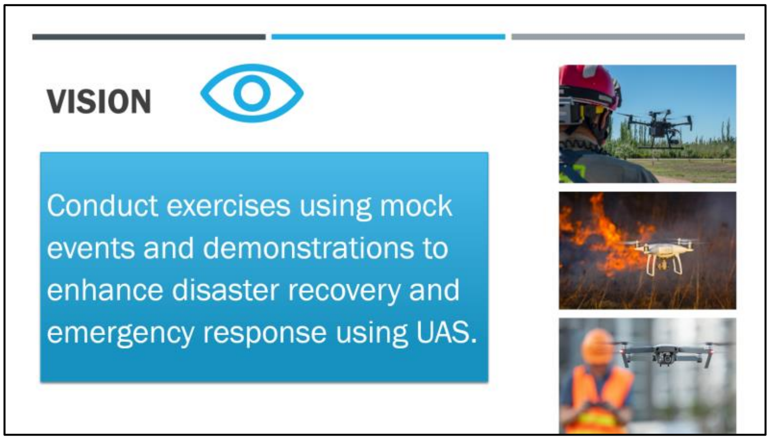



Figure 8. Vision for the mock exercise.

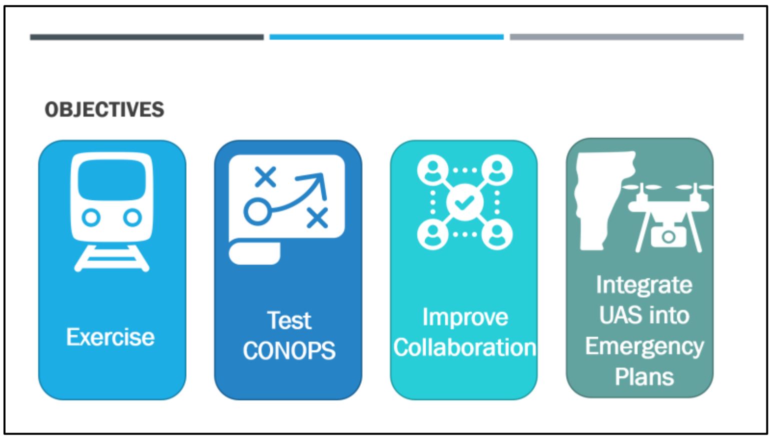



Figure 9. Objectives for the mock exercise.

- Examples of how sUAS have been used in the past for real world disaster response as well as in training and drills for the first responder community.
    - UVM's UAS Team has responded to a train derailment, flooding, ice jams, and other incidents throughout the state of Vermont that showcase the utility of the technology. They have also hosted workshops for professionals, promoting learning and exchanging of knowledge in the UAS and GIS field.
    - Outside of Vermont, there are multiple organizations that employ UAS, such as the New York City Fire Department. These connections were made to help get across the value of UAS integration into emergency response in Vermont, and hence the need for seminars and exercises to develop those CONOPs and collaboration.
- Possible locations for the exercise within Vermont, including the cities of Montpelier, Rutland, and Middlebury, as well as associated considerations such as terrain, line of sight, airspace restrictions, and pedestrian traffic in each area. It was highlighted that the exercise location should be a site that is somewhat realistic for the scenario and include some challenges to overcome without being too unsafe.

- Potential issues to address such as mobilization, airspace, data collection, data processing, and dissemination (Figure 10).
  - Mobilization refers to the process in which UAS support is requested and the UAS teams deploy for response. This was especially important to consider for UVM, which is not an official resource for the Vermont Emergency Operation Center. It was unclear what chain of command might look like for UVM or other UAS groups.
  - Airspace refers to the operation area and its associated regulations, which could potentially limit flight height. Areas in both Burlington and Montpelier have some level of restriction due to nearby airports, which would need to be considered when choosing a location for operations.
  - Data collection, processing, and dissemination refers to the UAS data to be collected to meet the goals of the operation, how to process it most efficiently, and then the best methods for sharing with stakeholders. Although the focus of the exercise would be geared more towards communication and coordination efforts during flight operations, the sharing of data is still a crucial step in emergency response.

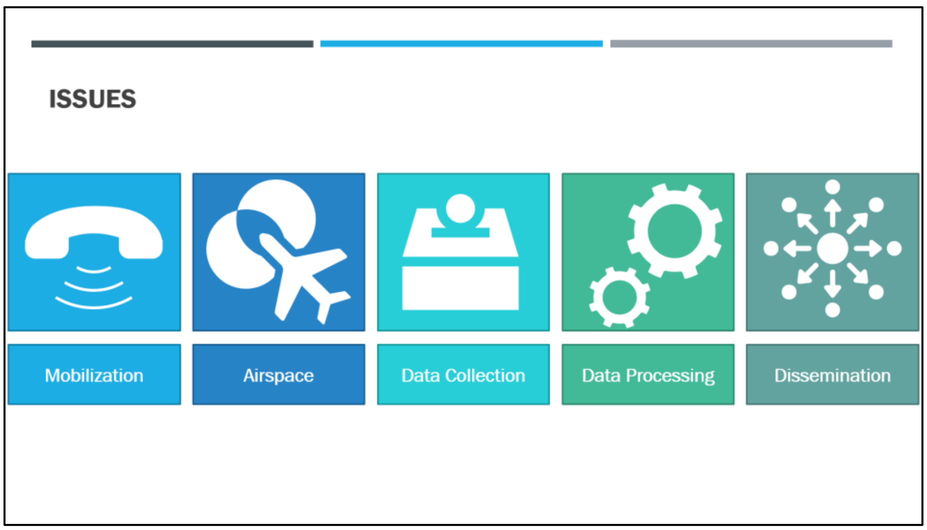



Figure 10. Issues to address during the mock exercise.

- The number and role of UAS flight teams, which should be sufficient to test communication and coordination efforts, but not unreasonable or unsafe.
  - It was decided that two to three teams seemed feasible based on interest and to deconflict airspace.
  - Based on capabilities and expertise from past operations, it was decided that UVM will provide mapping while VTrans will collect live stream video. This aligns well with experience level and ensures teams can practice and further develop their typical protocols.
- Based on communication and coordination issues, the role of “UAS Air Boss” was discussed, and who might be a good fit for that role.
  - Remaining questions included identification of the Air Boss, proper radio procedures, coordination with external groups who may be flying in the area, and other related airspace coordination/communication practices.

Other potential stakeholders were identified, including the Vermont State Police and or other local first responders who may wish to participate/observe if they do not have UAS.

### 2.11.4 Train Derailment Seminar Follow-Up Activities, If Applicable

The primary follow-up activity was for UVM to schedule the next seminar, develop a rough timeline for the event, and determine the participant list. It was decided to invite other important stakeholders such as VT Emergency Management, USAR VT-TF1, and other potential participants or observers who would benefit. This would serve to make connections between UAS operators in the region and the organizations they may need to work with during a disaster.

### 2.11.5 Lessons Learned from the Train Derailment Seminar, Including Responses to Research Questions

#### 2.11.5.1 Train Derailment Seminar Key findings:

1. Barriers may exist around mobilizing UAS teams during an emergency if there are no clear protocols in place for requesting UAS support.
2. There is no clear answer for the number of UAS operations feasible at the same time, as this can depend on the specific environment and situation.
3. With multiple UAS operations occurring at the same time, there is value in assigning an "UAS Air Boss" to coordinate airspace, but it is unclear the level of experience, training, or qualifications necessary.
4. Mapping and livestream missions were confirmed as being key tasks to support a train derailment response.

#### 2.11.5.2 Train Derailment Seminar Recommendations:

- Connect with the EOC, emergency managers, first responders, town planners, and related bodies to spread awareness of UAS capabilities and develop a protocol for UAS support requests for local, state, or larger response.
- Develop, assess, and refine procedures and CONOPs for multiple UAS operations at the same time under varying environments and situations to better understand best practices and limitations.
- Determine what responsibilities would be useful for an Air Boss and what experience would be necessary to designate a qualified person for the role.

#### 2.11.5.3 Train Derailment Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. Thus far, the seminar has determined the benefit of UAS to assist in a response such as a train derailment by keeping responders out of potential harm, providing a unique aerial perspective and situational awareness, and the ability to collect data for highly precise maps and terrain models for analysis. A live stream feed from a UAS would provide situational awareness while UAS mapping operations can collect data for analysis following the event.
2. N/A
3. Airspace coordination is a major concern, depending on location there is the potential for nearby airports with heavy air traffic. In areas with fewer occupied aircraft, there is risk in multiple UAS teams operating in the same airspace, as is planned for this exercise.

   Mitigations for external air traffic include:

- Notifying the nearby airport of UAS flight operations, if applicable;
- Monitoring an Airband Radio;
- Monitoring an ADS-B receiver ;
- Using one or more VOs to monitor the airspace.

Mitigation for multiple UAS operating at the same time include:

- Limiting operations to a reasonable number of UAS that can be safely tracked and managed;
- Partitioning the air space to avoid overlap in flight locations using horizontal and vertical buffers;
- Communicating flight maneuvers;
- Using an Air Boss to coordinate and communicate amongst flight teams.

4. N/A
5. N/A
6. N/A
7. N/A
8. N/A
9. N/A
10. There is a need for protocols or procedures in place to request UAS support or initiate deployment following an emergency. Whether this is built into an ICS or tasked by the EOC, there should be clear steps to most efficiently and effectively deploy UAS teams to the area where they are needed. Ideally, UAS teams are requested based on their capability to collect the required data, with priorities clearly defined.

    Refinement of an Air Boss role and their tasks during an operation to safely coordinate UAS operations is needed, as well as the required experience for the position. A certificate or credentialing pathway could help to standardize the role amongst organizations and prove proficiency when arriving on scene.

11. A local or small-scale train derailment could be suited for UAS due to the ability of UAS to get closer to the subjects of interest and utilize advanced sensors for specialized data products compared to occupied (manned) flights.

    UAS could also be beneficial in a situation where a train derailment happens along a corridor, allowing for efficient flight along the length of the rail as opposed to sending out a ground crew. Due to keeping VLOS with the UAS, it may no longer be feasible with increased distance between the control station and the UAS, resulting in losing line of sight or connection between the controller and the platform.

#### 2.11.5.4 Train Derailment Seminar Lessons Learned Summary:

For effective and efficient UAS response to a disaster such as a train derailment, there needs to be a protocol in place for UAS support requests, identifying types of data needed and organizations capable of collecting the data. Multiple mission profiles may be suited for the response, including live stream UAS video feed for real-time monitoring and mapping operations for post-event analysis. When multiple UAS operations occur at the same time, there should be refined procedures and CONOPs to guide safe operations, including the use of a UAS Air Boss to coordinate and deconflict air space.

## 2.12 3/30/2023, Workshop/Tabletop, Volcanic Eruption, Anchorage, AK, Conducted by UAF

### *2.12.1 Objectives of the Volcanic Eruption Workshop/Tabletop*

The workshop was held with similar objectives as the Seminar completed on January 4, 2023. The attendees also completed a Mentimeter survey similar to the one completed for the January Seminar (See section 2.4).

### *2.12.2 Planning for and Logistics of the Volcanic Eruption Workshop/Tabletop*

Professor Peter Webley, Associate Director of Research at the UAF-ACUASI, held a one-day workshop at the Applied Health Building on the UAF campus, starting at 8 am Alaska time. 10 people signed up to attend and, in the end, two attended in person and four attended online. Of the two in-person, one was a federal representative who had been involved in volcanic eruption response in the US (Hawaii) and used drones while the second in-person attendee was a private industry representative.

### *2.12.3 Volcanic Eruption Workshop/Tabletop Execution*

Webley led the participants through a set of slides that went step by step through the CONOPs for this use case. Time was provided for the attendees to provide feedback at certain times in the day-long workshop. This was done through printed forms that only collated the comments and the person's job description and organization type or through on-the-day notes that only connected comments made with the same categories.

### *2.12.4 Volcanic Eruption Workshop/Tabletop Follow-Up Activities, If Applicable*

From the recommendations, Webley from UAF-ACUASI developed an updated CONOPs for a Mt. Redoubt eruption, rather than Mt. Spurr, as this is more likely and be a key event that impacts Alaska and the Anchorage area.

### *2.12.5 Lessons Learned from the Volcanic Eruption Workshop/Tabletop, Including Responses to Research Questions*

#### 2.12.5.1 Volcanic Eruption Workshop/Tabletop Key findings:

1. Mt. Redoubt volcano would be more likely to response close to Anchorage.
2. UAS would support both day and night operations.
3. Anchorage International Airport could be closed.
    a. In case of this, there needs to be a backup location for lUAS operations.
4. How will ash and gasses degrade the airframe and sensors? Extra information is needed to create accurate checklists.
5. The UAS must fly into the plume (a BVLOS operation), so the UAS should have DAA capabilities.
6. Ash particulates could impact communications, which adds additional risk for ORA.
7. Data should be collected regarding the following:
    - How do UAS operators get real-time data to decision support? Where is it stored?
    - Is metadata necessary on who collected the data and what aircraft and sensor was used?

- Real-time data needs to be communicated to decision support. Post-mission: don't rely on the cloud, instead HDD backups should be used.

8. It would be nice to have AI/ML to determine the plume location to minimize the likelihood of flying through it.
9. sUAS #1, positioned at the summit, samples the lava lake or summit eruption to minimize people at risk.
10. sUAS #2, positioned at ANC, is 1K feet sufficient altitude to capture data for decision support?
11. lUAS, at a higher altitude, should move in a circular pattern to capture the full extent of the plume/cloud. Once detected, lUAS should map the tephra/ashfall on the landscape.
12. Additional safety briefings are necessary, given the significant hazard from the volcano.
13. Detailed assessment of hazards and projected activity are also necessary to determine if it is safe to fly.
14. The Quad Chart should include details on hazards and major risks, with critical maps on the back.

#### 2.12.5.2 Volcanic Eruption Workshop/Tabletop Recommendations:

- Ensure all flight crews have detailed checklists as drone/UAS support for volcanic eruption responses can be different from usual Part 107 flight operations.
    - Ensuring teams assess crew health was seen as important as well as additional engineering checks of the airframe given the hazardous volcanic material that the aircraft could encounter.
- Ensure all flight crew have additional safety equipment as they could come into close contact with volcanic ash and gases and so would need mitigation devices (air filters with masks) that they could use to continue to operate.
- Crews should know ongoing hazards so they could evacuate to safe zones if the volcanic event impacts their flight location including take-off and landing zone.

#### 2.12.5.3 Volcanic Eruption Workshop/Tabletop Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. Volcanic eruptions produce several hazardous impacts on the local environment and infrastructure where UAS can support the existing event response and mitigation. Each of these hazards leads to an impact where UAS can provide new opportunities to understand the event itself and support those responding to it. Volcanic eruptions and changes in volcanic activity are managed and monitored in the US by USGS volcano observatories (including some academic and state partners like in Alaska) along with regional volcanic ash advisory centers maintained by the NWS. Sub-set use cases include but are not limited to:
    - *Real-time Situational Awareness:* This is to provide visible and thermal feeds of the ongoing activity. This will support the volcano observatory on the extent of eruption including lava flows and eruption vent signals. Video feeds can also help to assess flow rates of the ongoing activity to determine future hazard extent and likelihood to impact local infrastructure.
    - *Post-flight Mapping:* These would be generated post-flights but during any ongoing eruption response. Products would include orthorectified imagery and composite maps (both visible and thermal). Products support decision-making teams during ongoing

events as well as post-eruption to assess ashfall/tephra extent, flow extent, and derived eruption volume estimations. Consideration is required for the dissemination of this data including all metadata to ensure it can be visualized by all entities in the response, whether from federal, state, local, academia, or private sector.

- *Real-time and Post-mission Sampling:* The products from volcanic events, such as ash and toxic gases, need to be sampled in real-time to assess any changes in the volcanic activity that can support eruption forecasting and to determine the potential dispersal extent of the plume and downwind clouds. Consideration is needed on the types of missions, altitudes to be flown including permissions needed, and impact on the aircraft to provide sustained observations to support the operational agencies.
- *Post-mission 3D modeling:* SfM processing from visible and thermal imagery can produce 3D models of the eruptive products and remaining summit topography post eruption. This data is extremely useful for volcano community to determine total eruption volume and to understand how the local landscape will recover after the event has ceased. Coupled visible and thermal 3D model data provides added actionable intelligence on the erupted products and if they are still a hazard to the local population and infrastructure.

2. Communication is key. It is important to ensure ground teams know the hazards from the event; ensure the UAS/drone team is aware of other uncrewed or crewed systems supporting the response; ensure that the teams are all aware of the airspace environment and involved in all daily briefings limits the impact of a lack of communication where a flight team might be a hindrance to operations. Two several specific components for consideration from the workshop were:

1. *Safety plans:* Ensuring that all groups involved had plans on how to evacuate if the activity changed and that they had components of their checklists that ensured mental and physical safety of the flight crew.
2. *Permissions for site access:* Depending on the location of the eruption, access maybe limited and/or safe landing zones required to response to hazards during flight maybe in areas of limited access. Communicating on likely safe zones for UAS with decision makers mitigated the chance of unexpected landings in inaccessible sites.
3. Five risks came up for discussion that were not included in the general or specific operational risk assessment shown to the workshop participants.
    - *Volcanically induced weather:* The volcanic event cause changes in the local weather patterns that put operations at risk. This causes landing zones to be inaccessible and/or return-to-home not possible. Flight crew will mitigate and ensure that they are aware of changing weather conditions and have backup options if a significant change in the conditions prevents flights from continuing.
    - *Bad actors:* There are people on the ground who want to get close to the eruption and are causing issues to the safe operations. This causes impact to safe operations as the bad actors want to interfere with the mission and are below the flight paths and/or close to the drone. Flight crew will mitigate this and set up safety barriers and work to see that the public do not cross them. If they do, then the flight team will take aircraft to safe locations, safe landings, or return to home so that flight is not a risk or further impact.

- *Volcanic hazard (Ash/SO2/CO2) degradation:* Significant volcanic hazardous material impacts the airframe and payload while in flight that makes the aircraft of limited use or unsafe to use. This will cause the flight crew to be unable to support the operational needs of those in the response. Flight crew will mitigate this through cleaning of systems between flights, minimizing the chance of debris hitting the aircraft in flight and vigorous assessment of the airframe and payloads after each flight.
- *lUAS airport closure:* Depending on the volcanic event, local earthquakes induced from the volcanic eruption may cause an airport to be inaccessible and/or become unusable during a flight or set of flights. This causes the flight crew of a lUAS to be unable to return to home and complete safe operations. Flight crew will mitigate this by defining backup locations where a lUAS can safely land and/or set up a backup site for take-off and landing if the impact occurs before the mission starts.
- *Wildlife in the flight zones:* Local wildlife in proximity to the volcanic eruption prevent the flight crew from reaching their defined take-off site and/or interfering with the operations while the flight is in process. This prevents the crew from setting up the mission and/or from being unable to safely operate. Flight crew will mitigate this by remaining aware of local potentially harmful wildlife, carrying safety gear to protect all the ground crew and having safe landing zones to send the aircraft, if the ground team is affected by local wildlife and has to leave their initial take-off and landing site.

4. These were developed by the A52 team for a volcanic eruption from Mt. Spurr Volcano in South-Central Alaska with an eruptive vent at the summit and attached plume as well as dispersing ash clouds towards Anchorage. A general hazards ORA that could occur in all use cases under A52 and specific hazards ORA for this use case were developed to accompany the CONOPs. Additionally, a quad chart and a suite of checklists added to the CONOPs and two ORAs.
5. A lUAS would provide higher altitude observations of the volcanic event and be able to sample the plume from the summit vent. A sUAS would be flown from the summit region to provide precision observations of the ground hazards at this location and vertical profiles through the plume. A sUAS would also provide downwind ash and gas measurements to support the decision team in predicting the cloud impact to Anchorage and its surrounding infrastructure.
6. There is no one optimum UAS to support all aspects of the volcanic use case and provide all necessary observations to support the eruption response. Based on this use case, specific requirements are needed by the operational agencies responsible for the event response, monitoring of the hazard, and mitigating its impact. sUAS systems can provide rapid response observational data that can operate from a small-footprint take-off zone and can be carried by team to get to locations not possible by crewed systems or lUAS. Sensors onboard provide specific observational needs, either visible cameras to build SfM 3D models, thermal sensors to determine heat flux from the event and/or flow speed, and ash and gas samples to assess the changing volcanic signals and support decision makers on the likelihood for an increase or decrease in activity levels. A lUAS can provide a high-altitude observational dataset not possible from small rotor UAS systems and can be flown to targeted locations at the need of the event response.
7. Any organizations wanting to integrate UAS into the event response and the NAS will need to follow local incident command structure as well as local and regional eruption response

protocols for responsible agencies and communication structure. UAS integration in this use case can then be seen as a benefit to the agencies responsible for preparedness, response, monitoring, mitigation, and impact assessment. UAS operators and flight crews can then follow FAA policy and regulations for NAS integration in parallel to becoming part of the event response tools and assets. For those organizations developing the next iteration of their event response protocols, adding in the opportunity that UAS provide and assessing the impact that they could provide to support the event response then they will have state-of-the-art tools available. These organizations should coordinate on the availability of local to regional UAS teams to then add them into the event response to benefit the decision-making process.

8. There was no direct reference to C2 links in the workshop. Airspace coordination was stated as important given the number of potential crewed and uncrewed systems. Also, control of the large and sUAS was included in the ORA with corresponding mitigation and discussed with the attendees.
9. Ensuring a safe network of UAS is highlighted in the ORA and having a flight crew be able to mitigate against any bad actors wanting to take control of the aircraft is a consideration in the ORA but was not discussed at the workshop. In terms of the data produced and products developed, discussions focused on how to make this accessible to all groups in the response. Attendees stated to produce all data in common formats that could be placed on secure servers that could then interface with the relevant software used by each organization.
10. For this use case, a volcanic eruption from Mt. Spurr, Alaska was selected for the event location. While this event may occur soon, operationally UAS/drones have been used at eruptions in Hawaii. Some of the recommendations from the workshop attendees, based on the potential for a Mt. Spurr event and from experience in Hawaii were:
    - Ensure all flight crews have detailed checklists as drone/UAS support for volcanic eruption responses can be different usual Part 107 flight operations. Ensuring teams assess crew health was seen as important as well as additional engineering checks of the airframe given the hazardous volcanic material that the aircraft could encounter.
    - Ensure all flight crew have additional safety equipment as they could come into close contact with volcanic ash and gases and so would need mitigation devices (air filters with masks) that they could use to continue to operate. Also, crews should know ongoing hazards so they could evacuate to safe zones if the volcanic event impacted their flight location including take-off and landing zone.
11. For a volcanic eruption use case, UAS can provide additional capabilities that would be difficult to collect from manned flights. These include:
    - Long-term high-altitude observations of the full extent of the volcanic event.
    - Continued night-time operations when manned systems are unable to operate.
    - Rapid response events with ability to switch out sensors for situational awareness.
    - Proximal access to volcanic hazard to support decision-making when risk is too high for manned systems.

#### 2.12.5.4 Volcanic Eruption Workshop/Tabletop Lessons Learned Summary:

Below are several important topics raised by those attending the workshop and from the comments made on that day. The experience of several of the attendees was invaluable as it highlighted the information that flight teams should know when supporting a hazardous event, such as a volcanic eruption, and that the teams should have knowledge of the flight environment to ensure safe operations as well as the volcanic hazard (ground and airborne) so that they can be a support team to other operations and not a hinderance to the other decision support teams and organizations.

- Is Mt. Spurr likely to erupt? What happens if Anchorage International is out of use?
- Who can conduct night operations and flights over people?
- Who has been involved in multi-flight operations, experience in real-time events?
- Will operators have permissions to reach > 400 ft AGL for downwind plume detection?
- Do the flight teams have BVLOS permissions?
- Do flight teams have risk assessment of crew fatigue and safety included in checklists?
- Do the flight teams know of the ongoing volcanic event risk and potential change?
- Does summit team have training and safety gear to operate around toxic environment?

## 2.13 4/11/2023, Workshop/Tabletop, Earthquake with Tsunami, Anchorage, AK, Conducted by UAF

### *2.13.1 Objectives of the Earthquake with Tsunami Workshop/Tabletop*

The workshop was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case. The attendees also completed a Mentimeter survey on their current capabilities and knowledge of UAS as applied to this use case. The survey only collected responses based on the organization type and position type of the attendees, and did not capture personally identifiable information.

### *2.13.2 Planning for and Logistics of the Earthquake with Tsunami Workshop/Tabletop*

Professor Peter Webley of the UAF-ACUASI held a one-day workshop at the Applied Health Building on the UAF campus, starting at 8 am Alaska time. 18 people signed up to attend and, in the end, four attended in person, and six were online.

### *2.13.3 Earthquake with Tsunami Workshop/Tabletop Execution*

Webley led the participants through a set of slides that went step-by-step through the CONOPs for this use case. Time was provided for the attendees to provide feedback at certain times in the day-long workshop. This was done through printed forms that only collected the person’s job description, comments, and organization type, or through on-the-day notes that only connected comments made with the same categories.

### *2.13.4 Lessons Learned from the Earthquake with Tsunami Workshop/Tabletop, Including Responses to Research Questions*

#### 2.13.4.1 Earthquake with Tsunami Workshop/Tabletop Key findings:

Comments made and suggestions on improvements were directly related to the components of the CONOPs and the slides within the workshop. Below is a summary of those comments.

1. Pilots and UAS teams should understand the ICS and have 100-level training.
2. Additional data – need to perform a Landslide and Rockfall assessment along the Turnagain Arm.
3. Additional data – Provide observations for the Port of Anchorage.
4. Add in ORA summary, Coordination, and logistics summary into the Quad Chart.

5. The number of drones was higher in public than during the '18 earthquake in Anchorage. How should this be coordinated with Operations?
6. A site survey should be performed to assess if the selected location has been impacted by the earthquake. Regardless, backup sites should be identified.
7. Add nautical charts, evacuation sites, and important local infrastructure (such as hospitals) to maps.
8. How can local good Samaritans be used to provide first eyes on the scene?
9. Collect a database of available Part 107 pilots for SAR as certified operators that can be called upon. Add in periodic training, and also have basic ICS training. Who manages this database?
10. Include in the maps any TFR and/or links to where these are available if in place.
11. All operators should have basic ICS training so that they know who to talk to and the flow of data and communications. Include FEMA 100 & 200 courses, with certificates in the mission folder.
12. Current CONOPs are for long-term mission development. What is the minimum needed if rapid response is required to support SAR?
13. Ensure that data collected is available post-mission to support After Action Review (AAR).
14. Add date and time to checklists so team knows if it is necessary to return to previous list.
15. Create a checklist to ensure the team has first aid and additional clothes/food/water/boiler to be able to be self-sufficient for two days.
16. Create a pre-flight checklist, including an airspace and weather check. (Potential need for an incident meteorologist is noted.)
17. Use LiDAR to support marine observations; compare how fast to get Red, Green, Blue (RGB) images versus 3D model.
18. For operations, what can be collected instantly to support SAR vs long-term for AAR?
19. It would be nice to have a UAS with a speaker to support SAR, even two-way communications.
20. Plan how to track pilot fatigue to minimize risk post-flight.
21. Post-Flight checklist should include a weather check to help long-term assessment of aircraft usability.
22. List issues that occur or record N/A to update logged operations post-mission.
23. Include metadata on who was on the flights, the sensor, and the aircraft used.
24. Add to EXIF for images or have metadata files in folder with data.
25. First, use Real-time RGB images; second, use High precision models to support AAR.
26. Assess gaps in data regularly. The UAS is optimized to support EM response.
27. How can the team respond to earthquake aftershocks or more tsunami impact to assist the community?

#### 2.13.4.2 Earthquake with Tsunami Workshop/Tabletop Recommendations:

- The drone flight teams should have FEMA Incident Management Team (IMT) training so are aware of protocols, processes, and workflows during an event and are less likely a hindrance.
- There needs to be a process to determine flight team fatigue so that they can be a supportive team for the operations and not put themselves, their team, and those they are supporting at risk.
- Flight teams need to show evidence of experience of flying in multi-aircraft environments as the airspace will be very busy during an event. The team needs to show that they have

and can continue to operate in a busy airspace and provide support to the existing operations and not be a risk.

#### 2.13.4.3 Earthquake with Tsunami Workshop/Tabletop Informed Research Question(s):

Findings from this Workshop/Tabletop were similar to the seminar completed on January 31, 2023; references to find the appropriate sections are noted below. The research questions outlined in Section 1.1 were informed by this event as follows:

1. See number one in Section 2.8.4.3 for details on the use case. Below are the important roles that UAS provide to support the operational agencies responding to an event as detailed in the use case workshop:
    - *Real-time Situational Awareness:* Here, video feeds (both visible and infrared) would support the ground teams to map the extent of the damage to the local infrastructure (buildings, roads) as well as the inundation of the tsunami event to the local community. Thermal data would allow the event response team to assess if any fires had started due to building collapse as well as to support teams in their SAR operations.
    - *Post-flight Mapping:* After each flight and mission, the visible and thermal imagery would be developed into orthorectified composite maps showing the extent of the damage from the earthquake on the region as well as the impact of the tsunami to the local community. These products would be developed to integrate into available data visualization tools, such as GIS software. The products can support SAR, building damage assessment, and after-action review for damage removal and recovery.
    - *Post-mission 3D modeling:* Building a digital surface model of the impacted zones from the earthquake event and tsunami inundation would support those in damage assessment and post-hazard analysis on the extent of the event and after-action review. Rapidly developed products provide those in building assessment to make informed decisions on the safety of the infrastructure and if they are accessible or inaccessible for ground response teams during the event response.

    The UAS systems to be used in this case would map the extent of the earthquake impact, assess a bridge post-collapse, and the inundation of a local community from a tsunami. Some of the attendees stated that UAS could also assess the potential for avalanche collapse that may result from the major earthquake and subsequent aftershocks. This would a preparedness support that a UAS can provide in addition to the event response, after the major event. Additionally, UAS could be used to map out road closures from landslides that would otherwise be impassible by ground crews. Each of these additional uses for UAS during this hazard event would each support SA, develop post-flight maps of the hazardous event, and produce 3D models of the surface for AAR.

2. The focus on this topic at the workshop was communication between the flight crews and the incident command structure, that would be in place to respond to the event. With a lUAS operating at a higher altitude to provide observations on the full extent of the earthquake, along with at least two sUAS in two separate locations, communicating the decision support needs will be important to provide the observations needed and for the flight crews to understand the current air operations. There will be a statewide procedure to respond to a large earthquake, with an EOC setup that follows ICS processes. Having flight crews understand this structure

and where they fit within the event response will be important along with communication between the flight crews themselves, any other air operations, and the air boss for the event response.

3. Several specific risks were highlighted by the attendees at the work:
    - *Data accuracy for damage assessment:* Flight crew do not have RTK capabilities and as a result cannot provide geospatial accuracy in the post-flight data products. This could result in inaccurate mapping of the damage and impact assessment and after-action review. The flight crew will mitigate this by including a check for the RTK equipment during their checklists before heading to the take-off location. These additional checks will ensure that the flight crew have all needed equipment to support safe operations and to generate the derived products needed for the event response.
    - *Communication loss to SEOC:* There is a break in communication between the flight crew and the lead air coordinator at the SEOC. This results in the flight crew being unable to adapt missions to the need of event response or receive updates on new flight operations from the SEOC. The flight crew will mitigate this by having a satellite phone as part of their equipment to increase the likelihood of continued communications and to continue their pre-defined flight patterns while monitoring the airspace for any new aircraft that is near their operations. This action will ensure safe flight operations, that the original observations required are collected, and that the crew can communicate to the SEOC, even if radio or call service is down.
    - *sUAS airframe breaks and unable to operate:* The sUAS supporting the mapping of the tsunami inundation breaks and cannot support the event response. This results in no situational awareness of the impact on the local community and a lack of observations for the event response agencies. Flight crews will mitigate this by taking additional airframe components to be able to replace any impacted components. The event response will mitigate this potential risk by having access to additional sUAS operators who can be added to the response if original crews can't complete missions. This action will ensure that there are UAS available to support the mapping of the tsunami inundation and that the actionable intelligence reaches those in decision support and event response.
    - *Pilots distracted by other air assets:* The UAS pilots and their observers are watching their flight operations and the airspace around the aircraft, and they are distracted by the additional crewed and uncrewed systems that are also in the National Airspace System (NAS). This results in the potential for air-to-air impact and unsafe flight operations. The flight crews will mitigate this by staying focused on their own aircraft and if they determine it is unsafe for their operations then they will return their system to home or land at a safe zone. They will inform the SEOC that they cannot carry out their flights and will wait until it is safe to continue. This action ensures safe flight operations, lower likelihood of any impact on all air operations, and minimizes the impact that the UAS has on hindering the event response and any SAR operations.
    - *UAS operations impacting safety of others in event response:* The UAS (both large and small) are hindering the other event response teams including the ground-based SAR teams. This results in the operational agencies being unable to complete their mission to support the event and carry out their duties. Flight crews will mitigate this by staying in communication with the SEOC to ensure that the flight operations do not impact other

operations and, when required, by returning to home, landing at a safe location, or moving to a holding pattern until safe to continue their flights. This action ensures safe flight operations and no impact to the other event response activities that the UAS are there to support.

- *No power to re-charge batteries for sUAS*: As a result of the earthquake event and tsunami inundation there is no available local power to support the sUAS operations and to provide a power source for the GCS. This results in the flight crew being unable to charge batteries and to provide power to the GCS. Flight crews will mitigate this by including generators in the equipment list and in their checklists. Crews will double-check and review that they have a fully charged generator so that they can operate as a stand-alone team. This action ensures that the team can operate as stated in their CONOPs and that the decision support and event response teams receive the data and derived products from the UAS flights.
- *Earthquake aftershocks:* The large earthquake has caused significant damage to the region. There are resultant aftershocks across the previously impacted zones that is causing further damage to the local infrastructure and potentially bringing new hazards into play. This results in originally safe areas for operations now at risk and/or inaccessible. The flight crew will mitigate this by staying in communication with the SEOC or event response lead to ensure they have all available knowledge on the earthquake hazard and safe-to-access zones. The flight crew lead will also ensure the safety of all their crew and evacuate the ground station (take-off and landing zone) if needed. This action ensures all flight crew are safe and that the flights can be completed safely, and that the aircraft operates safely in the NAS. If the crew must evacuate their ground station location during a flight, the PIC will ensure that the aircraft lands safely through a divert to land immediately operation, and when it is safe to access this site, they will retrieve the system.
- *Multiple tsunami waves into community:* One of the sUAS is requests to map the inundation of the first tsunami wave to impact the community. The flight crew will setup at a safe take-off and landing site to map the area. The SEOC or event response lead informs the crew of additional tsunami waves, or the flight crew sees them approaching. This results in their original take-off and landing site being impacted and unsafe to use. Flight crew will mitigate this by evacuating to a safe zone, as defined by local tsunami evacuation routes, or as informed by SEOC or event response lead. Flight crew will also ensure that knowledge of local evacuation routes and extent of potential tsunami inundation is included as part of their pre-deployment checklist and included as maps in their CONOPs. The crew will perform a DLI for the in-route aircraft and when it is safe to access this site, they will retrieve the system. This action ensure safety for all the flight crew and safe operations of the UAS in the NAS.
- *lUAS airport inaccessible due to earthquake hazard:* The original earthquake is significant, which makes the airport meant to be used for the lUAS operations unsafe for flight access. This results in the lUAS being unable to take off and complete the high-altitude flight operations to provide data to assess the full extent of the earthquake and tsunami damage. The lUAS flight crew will mitigate this by including additional airport locations as part of their site assessment so that they can still access the airspace needed to provide the operational response teams the data that they require. Also, if the airport becomes inaccessible during the missions, then the flight crew will use its own safety protocols to

ensure safe operations of the lUAS in the NAS. These actions will ensure the flights can be completed to provide the observations needed and to ensure no additional risks to safe lUAS flights in the NAS.

4. See section 2.8.4.3 number four.
5. See section 2.8.4.3, number five.
6. See section 2.8.4.3, number six.
7. For this use case, organizations who want to integrate UAS into the event response and the NAS will need to follow local, state, and regional incident command structure. It was specifically stated by attendees at the workshop that UAS operators and flight crews should all have some level of FEMA ICS/IMT training. Teams with IMT 100, 200, 700, and 800 training will understand the IMT as a setup for an event, like this use case, and be able to smoothly integrate into the support response and become an asset to the EOC. Depending on the location, there may be statewide emergency response plans in place that define the EMC structure and responsible operational agency for each aspect of the decision making and assessment. UAS integration in this use case should be evaluated with these plans in mind so that the systems can be seen as a benefit to the agencies responsible for preparedness, response, monitoring, mitigation, and impact assessment. UAS flight crews can follow FAA policy and regulations for NAS integrate in parallel to becoming part of the event response tools and assets. For those organizations developing the next iteration of their event response protocols, adding in the opportunity that UAS provide and assessing their impact that they could provide to support the event response then they will have state of the art tools available. These organizations should coordinate on the availability of local to regional UAS teams to then add them into the event response to benefit the decision-making process.
8. See section 2.8.4.3 number eight.
9. Ensuring a safe network of UAS is highlighted in the ORA and having a flight crew be able to mitigate against any bad actors wanting to take control of the aircraft is a consideration in the ORA, but was not discussed at the workshop. In terms of the data produced and products developed, discussions focused on how to make this accessible to all groups in the response. Attendees stated to produce all data in common formats that could be placed on secure servers that could then interface with the relevant software used by each organization.
10. Below are several recommendations from the attendee’s response to this use case:
    - All non-emergency response drone teams should have basic IMT training. This would be FEMA training and/or a digital badge or micro-credential that they can show like their Part 107 certificate. All Part 107 private pilots who want to support emergency response should have basic IMT training so when called upon then they can more effectively be integrated into operations.
    - Emergency response policies assess where UAS systems can be integrated and guidelines in place on how to integrate systems from operational agencies already in the response as well as integrating in other organizations with a high-performance track record.
    - UAS missions be defined based on the timeline of the event. Build processes to support rapid response flights to support SA and early-stage SAR. Build processes and guideline on the data and observations needs for infrastructure assessment and after

event reviews so UAS operations can collect the necessary high precision data to build the needed products.

- Build recommendations on how flight crews should archive the meta data on the team, aircraft, organization, etc. so that once raw imagery and/or derived products are analyzed either during or after the event then the end users can trace where it came from, what system was used, and from whom the data and products originated.
- There should be a database of Part 107 pilots in the region who could be called upon to support SAR. DOI has this for their personnel but there is not one for public users. These would be drone/UAS Part 107 certified users that can be called up. Include Periodic training so that all have basic response understanding and SAR needs. FAA has a list of all who passed Part 107 and registered in a State. But who keeps this data for operations? Like an emergency officer for a building at a company/organization. Get automated text when a need arises, and they can come to help and show Part 107 card and get orientated to need.

11. See section 2.8.4.3 number eleven.

#### 2.13.4.4 Earthquake with Tsunami Workshop/Tabletop Lessons Learned Summary:

Below are several important topics raised by those attending the workshop and from the comments made on the day. The experience of several of the attendees was invaluable as they spoke about other hazards that can come from an earthquake event, such as landslides and avalanches, as well as the aftershocks that follow a large event that was the focus of the use case.

- The drone flight teams should have FEMA IMT training so are aware of protocols, processes and workflows during an event and are less likely a hinderance.
- There needs to be a process to determine flight team fatigue so that they can be a supportive team for the operations and not but themselves and their team at risk as well as those that they are supporting.
- Flight teams need to show evidence of experience of flying in multi-aircraft environments as the airspace will be very busy during an event. The team needs to show that they have and can continue to operate in a busy airspace and provide support to the existing operations and not be a risk.

## 2.14 4/14/2023, Workshop/Tabletop, Oil Spill, Anchorage, AK, Conducted by UAF

### *2.14.1 Objectives of the Oil Spill Workshop/Tabletop*

The workshop was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case. The attendees also completed a Mentimeter survey on their current capabilities and knowledge of UAS as applied to this use case. The survey only collected responses based on the organization type and position type of the attendees, and did not capture personally identifiable information.

### *2.14.2 Planning for and Logistics of the Oil Spill Workshop/Tabletop*

Professor Peter Webley, Associate Director of Research at the UAF-ACUASI, held a 1-day workshop at the Applied Health Building on the UAF campus, starting at 8 am Alaska time. 34 people signed up to attend and, in the end, 4 attended in person and 11 were online. A volcanic eruption in Russia caused issues for several to attend in person due to the spreading ash cloud causing cancelled flights across Alaska. Several of the attendees have been involved in Oil Spill response events and integrate drones into the operational support and they provided extremely useful insight.

### *2.14.3 Oil Spill Workshop/Tabletop Execution*

Webley led the participants through a set of slides that went step-by-step through the CONOPs for this use case. Time was provided for the attendees to provide feedback at certain times in the day-long workshop. This was done through printed forms that only collected the person's job description, comments, and organization type, or through on-the-day notes that only connected comments made with the same categories.

### *2.14.4 Oil Spill Workshop/Tabletop Follow-Up Activities, If Applicable*

Outcomes from the workshop were to develop a different oil spill CONOPs over land and with a smaller spill volume, as this is more likely and where UAS can provide a major difference. Webley from UAF-ACUASI developed an additional CONOPs that focused on a small oil spill from the Trans-Alaska Pipeline System in Alaska.

### *2.14.5 Lessons Learned from the Oil Spill Workshop/Tabletop, Including Responses to Research Questions*

#### 2.14.5.1 Oil Spill Workshop/Tabletop Key findings:

1. The Alyeska Pipeline Company responds as owners of the facility. They are supported by The Alaska Department of Environmental Conservation with other state, local, and federal agencies.
2. sUAS could be used to map the oil shine in the harbor.
3. Live video feeds have been fed back to IMT for oil spill drills in Alaska.
4. Power availability for all components is an issue in Alaska given remoteness.
5. Other hazards can include impact of the UAS operations on the local wildlife.
6. UAS teams need guidance from the PIC/VO to minimize impact to wildlife.
7. sUAS could support SCAT teams to locations where they cannot send boats and people.
8. Update the quad chart to include: who is on the team, what is the flight plan, and what will the team do to support response?
9. Operations should prioritize the immediate need, extent of contamination, and gross estimate of the spill.
10. How can UAS assist to map complication coastlines?
11. Are there sensors to include on UAS to "detect" and possibly categorize the oil (thick versus thin oil, what type of oil…etc.)?
12. UAS should provide a quick pop-up mission at 25ft AGL to understand extent of the event.
13. Can ML/AI be added into the data stream to interpret information for decision support?
14. The team should include wildlife observer to respond quickly to operations around local wildlife.
15. How do UAS teams send data back to operations? (Can they use File Transfer Protocol, Starlink, Microwave…etc.?)
16. Can the UAS be a mobile IP with data feeds that can be viewed anywhere?
17. To survey the extent of the spill, backup sites are needed. Is predicted spill movement an issue?
18. Survey wildlife in the region to determine if safe for operations.

19. Team will need to know ICS protocols to react and provide benefit, not hinderance.
20. Maps should include tidal changes at sites, local wildlife zones, and global reference systems.
21. It is necessary to keep track of the weather forecast over the region as well as at altitude of missions.
22. Mission checklist should include first aid training and notate either sunrise or sunset to be aware if it is a Night OP.
23. Mission types – First: large scale view to help deploy other assets, discover the extent of view over land vs. ocean, and make SA observations. Second: high precision data to help with long term impact and any AAR.
24. Once the first mission to support EM response is completed, longer flights can be planned.
25. Tethered UAS provides real-time feed over the bay and large scale continued eyes on operations.
26. UAS observations support derivation of relative thickness to supplement satellite data.
27. Data archiving is a challenge because of the volume of data – Flight logs as CSV. Metadata on flight crew, aircraft, sensors etc.
28. Issues with long-term response could push the team to perform night operations.
29. Wildlife impact (such as harassment of wildlife by UAS and of UAS by wildlife) is an ORA.
30. The team needs to be aware of any cultural heritage sites in the area.
31. Make a quick response version versus long-term mapping response in the CONOPs.
32. Looking to the future, how does AI/ML fit in? What's coming?
33. A detail missing in the use case was that a small spill, where only one team would respond, (Part 107 operations) would be a more common response type in AK.

#### 2.14.5.2 Oil Spill Workshop/Tabletop Recommendations:

Below are several important topics raised by those attending the workshop and from the comments made on the day. The experience of several of the attendees was invaluable. Several of those groups directly involved in oil spill response said that: (1) a small spill on land from the existing pipeline systems would be more likely and could benefit from drones; (2) situational awareness of the first estimate on the size of the spill would be most useful and help to deploy other assets in the event response.

- Drone teams should have FEMA IMT/ICS training to understand protocols and decision-making process.
- Drone teams should be aware of local wildlife hazards and the impact that their operations could have on the wildlife in the area.
- It is important to have metadata of the aircraft, payload, and team attached to the data so that anyone analyzing the data is aware of its source.

Drones could provide a quick response mission to support other operations and determine where to send out other assets. As a result, the drone team will be part of the early response and also need to know the potential for further hazards from the event, and not just be a part of the spill clean-up response.

#### 2.14.5.3 Oil Spill Workshop/Tabletop Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. This use case is a spill from an oil terminal in Alaska that impacts both the surrounding land surfaces and spreads across the Bay. There is also a need to map the impact of the event that led to the spill at the terminal itself. The different components of the event response led to a subset of use cases under this event where UAS will provide actionable intelligence. Below are the important roles that UAS provide for this oil spill event:
    - *Real-time Situational Awareness:* Here, video fees (both visible and infrared, including combined VNIR) would support the ground teams to map the extent of the damage to the terminal infrastructure as well as the oil spill spread across the region. Thermal data would allow the event response team to assess if any fires had started due to terminal collapse. VNIR data useful to assess extent of oil on land. Thermal/visible useful to assess extent on water. Combined data used to determine gross estimates of oil spill as first observations above the event before other assets placed for response.
    - *Post-flight Mapping:* After each flight and missions, the visible, VNIR, and thermal imagery would be developed into orthorectified composite maps of the extent of the spill and any damage to the terminal. These products would be developed to integrate into available data visualization tools, such as GIS software. The products can support SAR, building damage assessment, and after-action review for damage removal and recovery.
    - *Post-mission 3D modeling:* Building a digital surface model of the impacted area from the oil spill would support those in damage assessment and post-hazard analysis on the extent of the event and after-action review. Rapidly developed products provide those assessment team to make informed decisions on the safety of the terminal and if they are accessible or inaccessible for ground response teams during the event response.
    - *Oil Sampling, Ignition, and retardant mitigation:* sUAS could provide response teams proximal access to the oil spill and its extent across the landscape and water surface. sUAS could sample the oil to assess its thickness and consistency, as well as carry ignition equipment to burn the oil in place and then place retardant to mitigate the fire and support those water surface equipment herding up the oil.

    The UAS used in this case would map the extent of the spill and provide situation awareness of where to send other assets to mitigate the oil spread and its impact on the surrounding region. Several of the attendees, especially those who had been in spill response and used UAS, stated that more likely a spill would be from the pipeline itself and smaller in size. Therefore, early-on SA is essential to understand the spread of the oil and where to send other ground assets to limit the spread and its impact.

2. See section 2.7.4.3 number two.
3. Findings were similar to the Seminar conducted on January 30, 2023. See section 2.7.4.3 number three. Several more specific risks were highlighted by the attendees at the work:
    - *Communication loss to SEOC:* There is a break in communication between the flight crew and the lead air coordinator at the SEOC. This results in the flight crew being unable to adapt missions to need of event response or receive updates on new flight operations from the SEOC. Flight crew will mitigate this by having a satellite phone as part of their equipment to increase likelihood of continued communications and to continue their pre-defined flight patterns while monitoring the airspace for any new

aircraft that is near their operations. This action will ensure safe flight operations, that the original observations required are collected, and that the crew can communicate to the SEOC, even if radio or call service is down.

- *Operations moves from day to night operations:* Given the time of year, the flight crew operations continue long into the day and towards the local nighttime and the crew is not set up to operate a night. This results in the team flying without nighttime safe equipment and putting themselves and others at risk. Flight crew will mitigate this by having nighttime equipment on-board their aircraft if there is the potential for their operations extending into local twilight or nighttime operations. This action will ensure that the team can fly as long as possible in the given conditions and ensuring a safe mission. Those teams with potential twilight or nighttime operations will add to their checklist to ensure that this equipment is included. If there is no option to continue, given the light conditions, then the team will end their operations and flights, inform the air operations led, and return to pre-deployment location in preparation for next day's operations.
- *Drop in atmospheric temperature and conditions:* The local temperature at the ground control station/take-off and landing site and/or flight altitude drops below the safe operating range of the aircraft and/or the payload. This results in the airframe and/or payload have issues and failing. The flight operations will be impacted and potentially put the flight and other airborne assets at risk as well as those below the flight route. The aircraft could stop working midflight and be unable to land safely. Flight crew will mitigate this by continually tracking the temperature at the ground station and accessing National Weather Service data of the region that they are flying in. The crew will also keep a track of the system performance of the aircraft. This action will allow the flight crew to rapidly respond to a sudden change in the atmospheric temperature conditions. The crew will be able to set up a return to home/land operation to ensure safe flight operations or a divert to land immediately if the RTL is not possible.
- *Take-off/landing sites move as flown from moving vessel/boat:* A small VTOL UAS uses a take-off and landing location for its return to home. For this event case, a sUAS will be flown to support mapping of the oil spill impact to the oceanic environment and/or be used in a herder/burner mode to ignite the oil, in place, and to mitigate the burning oil. The boat being used losing its mooring and drifts from its original location when the aircraft took off. Therefore, the landing site and RTL location has moved and so if auto requested it will not return to the location of the flight crew. This puts the flight crew and other airborne and ground assets at risk. Flight crew will mitigate this by continually tracking boat location as compared to original take-off site and if RTL is requested then the crew will request this to be the current location of the boat and ask the skipper to keep the boat as close to this site as possible. The PIC will navigate the aircraft to the location of the flight crew and the boat once the aircraft returns for safe landing. This action always ensures that the flight is performed safely and that the crew has control of the aircraft.

4. These were developed by the A52 team for an oil spill from the Valdez terminal and subsequent spill onto the surrounding landscape and oceanic environment. A general hazards ORA that could occur in all use cases under A52 and specific hazards ORA for this use case were

developed to accompany the CONOPs. Additionally, a quad chart and a suite of checklists added to the CONOPs and two ORAs. Attendees at the workshop noted that for an oil spill event in Alaska, while this use case was a major event, the most likely is a small-scale spill from a land-based pipeline where there needs rapid assessment of the spill extent, mitigation of the hazard, and clean up.

5. Findings were similar to section 2.7.4.3 number five. Additionally, attendees at the workshop stated that additional sUAS, hexa- and octa-copter VTOL systems, could be used for several other components of the use case. These included but were not limited to: SCAT assessment, and monitoring of response assets to support targeted deployment.
6. See section 2.7.4.3 number six.

   Additionally, UAS can have two roles. One as rapid response situational awareness tool that can get observations on the event impact before any ground crews need to be placed and before other airborne assets can be deployed. The second role is to provide precise data and observations of the hazards and their impact for infrastructure assessment and after-action review of the event impact. This secondary role requires more precise data and can be collected by a UAS that operates around the other ground and air response teams.

7. For this use case, organizations who want to integrate UAS into the event response and the NAS will need to follow local, state, and regional incident command structure. It was specifically stated by attendees at the workshop that UAS operators and flight crews should all have some level of FEMA ICS/IMT training. Teams with IMT 100, 200, 700, and 800 training will understand the IMT as setup for an event, like this use case, and be able to smoothly integrate into the support response and become an asset to the EOC. Depending on the location, there may be statewide emergency response plans in place that define the EMC structure and responsible operational agency for each aspect of the decision making and assessment. UAS integration in this use case should be evaluated with these plans in mind so that the systems can be seen as a benefit to the agencies responsible for preparedness, response, monitoring, mitigation, and impact assessment. UAS flight crews can follow FAA policy and regulations for NAS integrate in parallel to becoming part of the event response tools and assets. For those organizations developing the next iteration of their event response protocols, adding in the opportunity that UAS provide and assessing their impact that they could provide to support the event response then they will have state of the art tools available. These organizations should coordinate on the availability of local to regional UAS teams to then add them into the event response to benefit the decision-making process.
8. There was no direct reference to C2 links in the workshop. Airspace coordination was stated as important given the number of potential crewed and uncrewed systems. Also, control of the large and sUAS was included in the ORA with corresponding mitigation and discussed with the attendees.
9. Ensuring a safe network of UAS is highlighted in the ORA and having a flight crew be able to mitigate against any bad actors wanting to take control of the aircraft is a consideration in the ORA but was not discussed at the workshop. In terms of the data produced and products developed, discussions focused on how to make this accessible to all groups in the response. Attendees stated to produce all data in common formats that could be placed on secure servers that could then interface with the relevant software used by each organization.

10. See section 2.7.4.3 number ten. In addition, attendees highlighted that UAS could provide additional support to the event response, including but not limited to SCAT assessment and asset management monitoring. Below are several recommendations from the attendee's response to this use case:
    - All non-emergency response drone teams should have basic IMT training. This would be FEMA training and/or a digital badge or micro-credential that they can show like their Part 107 certificate. All Part 107 private pilots who want to support emergency response should have basic IMT training so when called upon then they can more effectively be integrated into operations.
    - Team members in SEOC trained on how to interpret data from UAS. This would be to have those in the SEOC be able to take the UAS real-time data and derived products and use them directly in the event response without having to get the flight crew and/or UAS operations team to interpret the data. This can be done through a remote sensing expert being in the SEOC and/or a specialist in UAS operations who can provide the actionable intelligence from the data.
    - Flight crews all aware of wildlife impact from UAS and wildlife impact to UAS. For this specific use case, as well as for others in areas of protected wildlife, UAS flight crews need to be aware of the protected areas and which areas might be inaccessible or unsafe to enter. These restrictions could change during the day, depending on the wildlife, and so gaining real-time insight and instructions from a local biologist/wildlife expert would be critical. Also, having this information within a flight crews' checklist, with its maps, would be a useful addition to the CONOPs and crew checklists.
    - UAS used as first situational awareness tool to get gross estimate of spill. UAS could provide fast response operational support on the estimated spill. This data can support the response teams to understand the extent of the event and the potential ground and oceanic assets needed to mitigate the spill and its spread. This would be a recommendation on supporting fast approval of UAS operations so that the data can be collected efficiently, effectively, and safely to support the event response.
    - Coordinate sUAS to get observations in small inlets. For this use case, along with the fast response for gross spill estimates, the sUAS would be extremely useful for mapping the spill as it extends into the small inlets and support ground asset allocation. This would require a coordinated response between the UAS crews and those cleaning up the oil in this inlet regions. Communication will be key as well as ensuring the ground/ocean crews can also access the real-time data to support their decision making of where to travel to mitigate the spread and remove the oil.
11. See section 2.7.4.3 number eleven.

## 2.15 4/24/2023, Workshop/Tabletop, Wildland Fire: New Fire in Satellite Data, Anchorage, AK, Conducted by UAF

### *2.15.1 Objectives of the Wildland Fire: New Fire in Satellite Data Workshop/Tabletop*

The workshop was held to showcase the use case to the wider UAS and disaster response community and to get their feedback on the developed use case. Additionally, all attendees were asked to complete a Mentimeter survey to record relevant knowledge and capabilities regarding the use of UAS in this specific use case. It should be noted that the survey did not collect any personally identifiable information.

### *2.15.2 Planning for and Logistics of the Wildland Fire: New Fire in Satellite Data Workshop/Tabletop*

Professor Peter Webley, Associate Director of Research at the UAF-ACUASI, held a 1-day workshop at the Applied Health Building on the UAF campus, starting at 8 am Alaska time. 18 people signed up to attend and, in the end, 3 attended in person and 3 were online. Several of the attendees have been involved in wildland fire response events and been part of the support network for those first responders and decision makers.

### *2.15.3 Wildland Fire: New Fire in Satellite Data Workshop/Tabletop Execution*

Webley led the participants through a set of slides that went step-by-step through the CONOPs for this use case. Time was provided for the attendees to provide feedback at certain times in the day-long workshop.

### *2.15.4 Lessons Learned from the Wildland Fire: New Fire in Satellite Data Workshop/Tabletop, Including Responses to Research Questions*

#### 2.15.4.1 Wildland Fire: New Fire in Satellite Data Workshop/Tabletop Key findings:

1. UAS can be useful when conditions are too smoky for manned systems.
2. Add in the number of people, who is on the mission, and their contact information into the Quad Chart. Where is this data to be stored?
3. These are some examples of useful data to support – wind profile above PBL and a high-resolution map of the fire.
4. Things to survey onsite: what are the local hazards? Is the fire predicted to reach the site? Regardless, backup locations are needed.
5. Maps should include medical facilities, population density/locations, vegetation map, and weather maps.
6. Things to consider in airspace coordination include: communications to Air Boss/ICS lead, and where are the manned systems?
7. Mission checklist should include protocols in case of an emergency. (Is there medical facilities nearby?)
8. Pre-deployment checklist should include weather check at ground and flight altitude, It is advantageous to have an Incident Meteorologist on site.
9. Risk is added if team has not completed checklist. What is the impact on operations, and what is the action plan?
10. Fly downwind sUAS over Fairbanks for air quality assessment.
11. Mission: What is base data to help on change detection? Is there any yearly coverage?
12. General comments and questions include: what is experience of the operations team to flying around multiple aircraft, and what are team skills and history? How do four sUAS teams communicate? How does VO communicate with their PIC?
13. A Log Sheet should be in place for multiple sensors and batteries per mission. Add in the number of GPS satellites.
14. Metadata on the flight should be archived, but where should it be stored?

15. Required training for flight teams should include ICS 100 and 200 as well as National 700 and 800.
16. General ORA should include birds in the airspace, dense air traffic, and bad actors.
17. Specific ORA should include change in winds, lack of knowledge on fire location, fire intensity increase, and air quality risk to crew.
18. Objectives should be used as metrics of success: map the perimeter, support ground crews on the containment, update overnight map, and collect data that can be interpreted by those in decision support.

#### 2.15.4.2 Wildland Fire: New Fire in Satellite Data Workshop/Tabletop Recommendations:

Below are several important topics raised by those attending the workshop and from the comments made on the day. The experience of several of the attendees was invaluable.

- Drone teams should have FEMA IMT/ICS training to understand protocols and decision-making process.
- Drone teams should provide evidence of the experience in operating in busy airspace environments and hazardous response. Not just as simple as having Part 107 and turning up to provide air support.
- Flight teams need to show that they are self-sufficient and can minimize any hinderance on the other support teams and the ICS so that are assets to the operational response.

#### 2.15.4.3 Wildland Fire: New Fire in Satellite Data Workshop/Tabletop Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. This event of a newly detected wildland fire from satellite data led to several different use cases where drones and UAS can operationally support the event response. There are several hazardous impacts to the surrounding landscape and infrastructure where a drone/UAS can minimize putting personnel at risk and supplementing existing assets.
2. See section 2.5.4.3 number two. Additionally, teams should check on any PIREPS. What is the weather at flight location and altitudes to be flown? In-reach system, check it works. Check with incident meteorologist on potential fire spread and plume dispersal.
3. A general ORA for those risks that could impact all use cases under A52 and a specific ORA for this use case are coupled to the wildland fire response. Several specific risks were highlighted by the attendees at the work:
    - *Understanding airspace and environment:* How will UAS/drone operators respond to a change in the fire weather conditions? Will want to get data off aircraft, in case it could be lost due to incoming fire, and so will need real-time need to ground or AI/ML that sends derived products in-flight. Birds/wildlife in airspace - how will team respond? Dense airspace with many airborne assets - how does team respond? Loss of data streams? Bad actors in the airspace?
    - *Access to flight metadata:* All flight teams should use standard format, and defined location so can be access from same place for all missions. With raw format, need all accompanying information so that anyone who gets the data can easily generate derived products without needing to get back to flight team. This is important if there is an

after-action report and assessment of the event response where flight data will need to be coordinated.

4. See section 2.5.4.3 number four.
5. See section 2.5.4.3 number five.
6. See section 2.5.4.3 number six.
7. See section 2.5.4.3 number seven.
8. See section 2.5.4.3 number eight.
9. See section 2.5.4.3 number nine.
10. See section 2.5.4.3 number ten.
11. See Section 2.5.4.3 number eleven.

#### 2.15.4.4 Wildland Fire: New Fire in Satellite Data Workshop/Tabletop Lessons Learned Summary:

Lessons learned focused on ensuring that the teams supporting disaster response to a new satellite detected wildland fire event should have FEMA IMT/ICS training to understand protocols and decision-making process. This will provide them with an understanding of the operational structure in an event response and provide a beneficial support to the operations and not a hinderance. Drone teams should provide evidence of the experience in operating in busy airspace environments and hazardous response. It’s not just as simple as having Part 107 and turning up to provide air support. Flight teams need to show that they are self-sufficient and can minimize any hinderance on the other support teams and the ICS so that are assets to the operational response.

## 2.16 5/17/2023, Seminar, Airport Terrorism, Huntsville, AL, Conducted by UAH

The scenario for this seminar was as follows – Huntsville International Airport (HSV) was selected as a landing site for the Dream Chaser, Sierra Nevada Corporation’s line of commercial spacecraft. The inaugural landing of Dream Chaser at HSV is expected to draw large crowds surrounding the Airport Operations Area (AOA) which has several locations on local and county roads as well as interstate highways. The event will include a multi-agency public safety preparedness effort with local, state, and federal law enforcement, fire/rescue, and emergency medical personnel on standby. During the event, multiple authorized UAS will be operating to provide situational awareness for public safety as well as media outlets reporting on the event. ATC has denied countless LAANC requests for commercial and recreational remote pilots from the public who wish to observe and record the Dream Chaser landing from a personal UAS. Law enforcement and airport authority public safety subsequently respond to multiple unauthorized UAS spotted in the area.

One response led to an unauthorized UAS causing havoc to authorized UAS conducting safety monitoring missions, leading to a crash into the public viewing area. An unauthorized quadcopter falls into the bleachers, injuring two people, one severely. Another unauthorized UAS was successfully countered but caused a small battery fire in the field adjacent to the AOA, ¼ mile behind the observation bleachers.

Additional support from federal Counter-UAS operators provide unique multi-agency interactions.

### *2.16.1 Objectives of the Airport Terrorism Seminar*

The Airport Terrorism seminar was meant to discuss the risk of UAS incursion on airports and during special aviation events. The seminar mostly consisted of the risk of UAS incursions at airport and the use of detection and mitigation technologies available used in low-altitude airspace management. The seminar also introduced the tabletop drill that would be hosted following the seminar.

### *2.16.2 Planning for and Logistics of the Airport Terrorism Seminar*

This seminar and follow-on drill were hosted during the large-scale UAS and Counter Unmanned Aircraft System (C-UAS) technology symposium event in partnership with the HSV, Skyfire Consulting, LLC, and C-UAS Hub. The "Future Proof UAS & C-UAS Summit" was a three-day event focused on showcasing the current technology for C-UAS and low-altitude airspace management. Over 250 attendees were present at the symposium from local/state/federal government agencies and industry involved in UAS/C-UAS development. The ASSURE seminar on Airport Terrorism was advertised daily at the Future Proof Summit and took advantage of the existing event infrastructure, for instance, an event tent, temporary restrooms, and televisions, to host the seminar.

### *2.16.3 Airport Terrorism Seminar Execution*

The presentation of the seminar was executed during one of the UAH talking sessions of the Future Proof UAS and C-UAS Summit.

### *2.16.4 Airport Terrorism Seminar Follow-Up Activities, If Applicable*

This seminar was a tabletop drill with local law enforcement in Huntsville, AL developing "Drone First Responder" programs.

### *2.16.5 Lessons Learned from the Airport Terrorism Seminar, Including Responses to Research Questions*

#### 2.16.5.1 Airport Terrorism Seminar Key findings:

1. Drones are useful in response to a terrorist event, but not in its prevention.
2. The restricted airspace in and around airports present specific challenges when employing disaster response UAS in that environment.
3. Following an airport terrorist event, drones were particularly useful in damage assessment, SAR, and image gathering for forensic use.
4. sUAS multi-rotor aircraft were deemed best for all emergency response CONOPs.

#### 2.16.5.2 Airport Terrorism Seminar Recommendations:

- The development of processes, standards, policies, procedures, etc. need to be refined by a combination of agencies involved in all aspects of every imaginable disaster.
- The use of UASs in disasters may require technologies that don't yet exist (e.g., UAS Traffic Management (UTM)) and the requirements for these technologies can't effectively be defined by individual stove piped agencies.

#### 2.16.5.3 Airport Terrorism Seminar Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. Drones are not useful in preventing a surprise airport attack. It's not feasible to keep drones permanently airborne in the sensitive airspace around airports.

Drones are useful for post-attack for damage assessment, SAR, situational awareness, target tracking.

2. N/A
3. In operations near or within airports, congested and restricted airspace are issues. In an emergency, close coordination with ATC and minimizing the number of drones in use at any one time are the mitigating factors.
4. No CONOPs were deemed to be useful in preventing an attack. Post-attack, CONOPs using sUAS for damage assessment, SAR, and image gathering for forensic use were examined. Mitigation included minimizing number of concurrent flights, close coordination with airspace management.
5. All aircraft were assumed to be sUAS multi-rotor.
6. In this disaster scenario, no UAS were optimum for disaster preparedness; sUAS multi-rotor aircraft were deemed best for all emergency response CONOPs. (See question 4 above)
7. It will be imperative to ensure common language and procedures between the ATC function and all emergency response organization making use of drones.
8. N/A
9. N/A
10. The development of processes, standards, policies, procedures, etc. need to be refined by a combination of agencies involved in all aspects of every imaginable disaster. The use of UASs in disasters may require technologies that don't yet exist (e.g., UTM) and the requirements for these technologies can't effectively be defined by individual stove piped agencies.
11. This seminar points out that multi-rotor sUAS are particularly suited to post-event damage assessment and SAR that require close proximity flying within a relatively localized field of interest.

#### 2.16.5.4 Airport Terrorism Seminar Lessons Learned Summary:

Within the limitations imposed by restricted airspace regulations, UAS were extremely valuable after a terrorist event in damage assessment, SAR, and image gathering for forensic use. Multi-rotor sUAS are particularly suited to post-event damage assessment and SAR that require close proximity flying within a relatively localized field of interest.

## 2.17 5/18/2023, Workshop/Tabletop, Train Derailment, Burlington, VT and Online, Conducted by UVM

The second train derailment exercise planning meeting was both in-person and virtual to allow for flexibility in attendance. This workshop provided the opportunity for the group to continue exercise development after the initial seminar and dive deeper into the questions that arose. This meeting was hosted by the UVM SAL Director and UAS Team Lead. In attendance were the UVM Emergency Management Director, VTrans UAS Program Director, and Emergency Planner from Vermont Emergency Management, in addition to other members of the SAL UAS team including staff, students, and interns.

### *2.17.1 Objectives of the Train Derailment Workshop*

The objectives of this workshop were to identify key partners, participants and resources; select a location for the exercise event; develop an implementation plan; and discuss how the exercise event can inform Vermont's use of sUAS in disaster response and recovery.

### *2.17.2 Planning for and Logistics of the Train Derailment Workshop*

This train derailment workshop was planned at the conclusion of the previous seminar, with UVM finalizing a date and sending out a Microsoft Teams invite for those who wished to meet virtually and booking a room on UVM's campus for those meeting in person. The SAL Director created and shared a PDF-format flyer inviting UAH and the FAA to attend.

Based on conversation during the previous seminar and the remaining questions, discussion topics were developed in advance by UVM.

### *2.17.3 Train Derailment Workshop Execution*

UVM presented information via PowerPoint including a reminder of the exercise vision and objectives, approximate timeline, issues to solve, and logistics such as team roles and platforms. Throughout the presentation, open discussion was held amongst participants to provide input, questions, concerns, suggestions, and other valuable insights. Following the presentation, conversations expanded on these topics and any other relevant considerations. A variety of topics were discussed to continue planning out the logistics of the mock exercise including, but not limited to:

- Location:
    - The exercise will take place near the Burlington Waterfront Urban Reserve Park in Burlington, VT. This site was chosen because inactive train cars are stored along the railroad, which could provide a realistic but safe scene for the mock derailment. Additionally, it was close to UVM, which could allow for collaboration with local contacts.
    - UVM will want to reach out to Burlington Parks, Recreation, and Waterfront who manages the land to discuss the usage and signage to block off public access during the event.
- UAS Capabilities and Roles:
    - UVM presented their capabilities and example data from a variety of platforms and sensors for either mapping (**Error! Reference source not found.**) or real time data collection (**Error! Reference source not found.**). This began conversation amongst teams about capabilities and expertise with different platform and sensor combinations, and identified how each group could assist to based on their strengths.
    - Mapping data and live stream video were chosen as key mission profiles for the mock train derailment exercise due to the ability for first responders and decision-makers to utilize the data products for after-action investigations and monitoring.
    - UVM would focus on LiDAR, EO, and multispectral data collection due to their platform/sensor capabilities and expertise in these areas.
        - Each of these mapping types would simulate collection that may be needed after a train derailment: 1) LiDAR to generate terrain models for analyzing the landscape and potential movement of spilled materials, 2) true-color mapping for documentation of the scene and generation of a 3D model for visualization and analysis, and 3) multispectral to potentially identify hazardous substances or other changes to the landscape that cannot be detected by the human eye.

    - As part of this mapping, UVM will operate a multi-rotor and a fixed-wing platform that is approved for flights over people, which is key given the exercise location and proximity to recreational areas.
    - It was decided that thermal mapping would not be a crucial data collection to test out during the event. Thermal information could be more valuable in real-time.
- VTrans would conduct "real-time" live stream video to provide situational awareness and simulate what might occur during a real-world event, in which case a live feed back to the EOC could be beneficial.
- An additional "media" or "invader" UAS could be used to simulate a potential disruption to airspace that pilots are not expecting, requiring deconfliction.

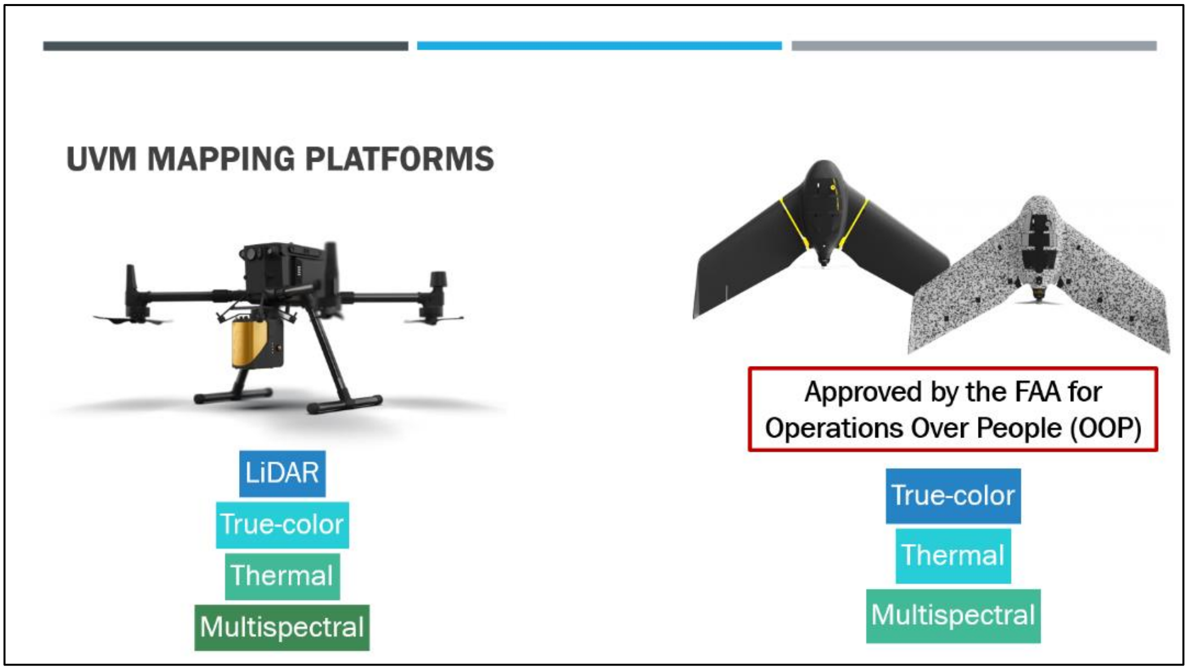



Figure 11. UVM platform options and capabilities for mapping.

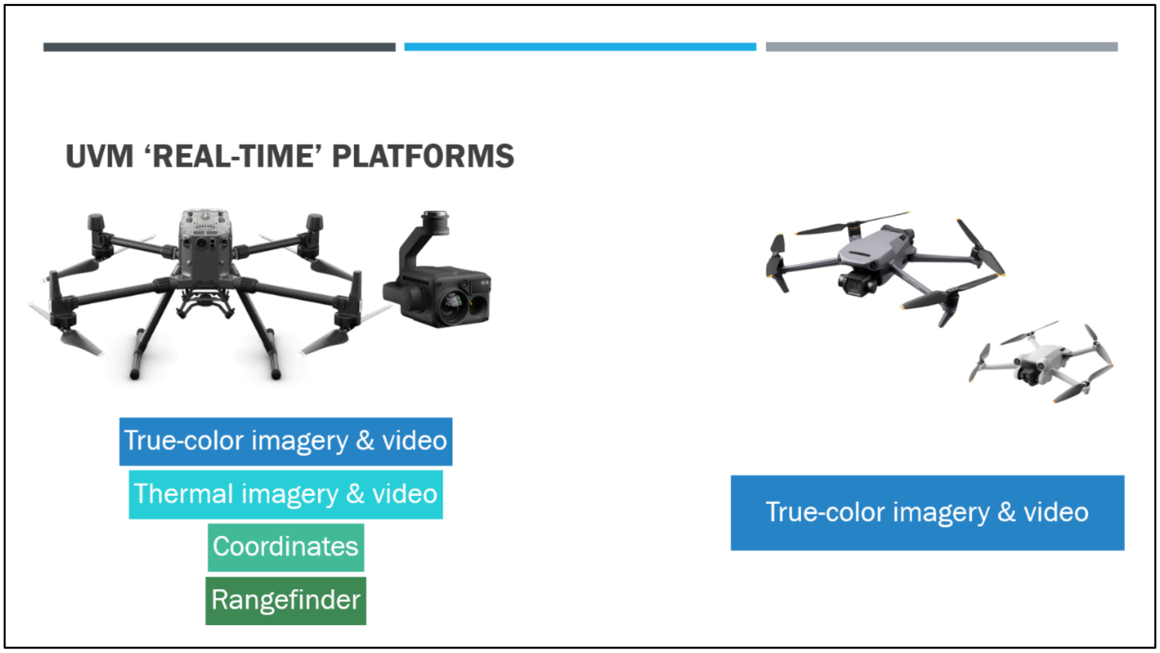



Figure 12. UVM platform options and capabilities for "real-time" data collection.

- Additional Participants
  - Vermont USAR VT-TF1 was identified as a potential group to involve, due to their expertise in SAR and thermal data collection. Many of their members were interested in getting more hands-on flight time and being able to collaborate with other UAS groups in the state.
  - Additional participants, stakeholders, and observers may include Vermont Center For Geographic Information (VCGI), Burlington Police Department, Burlington Fire Department, Vermont State Police, or Agency of Natural Resources due to their interest in either UAS or the resulting data products.
- Airspace Coordination
  - The UAS Program Manager from VTrans was selected to serve as the "UAS Air Boss." To keep focus on this role, the Air Boss would not be piloting any platforms. This role was intended to monitor the status of flight operations, conduct communication between groups, ensure safe airspace, and carry out other tasks related to the safe operation of multiple UAS in the same airspace.
  - Potential airspace coordination and visualization tools were discussed. It was undecided if complex software solution would be helpful, or a simple whiteboard would be better to help track and partition air. Ultimately, it was decided to focus on a method that could be easily repeatable by different organizations.
- Data Sharing and Dissemination
  - UVM will be responsible for processing and dissemination of data products.
  - No concrete solutions were chosen for sharing the products, but it was evident that dissemination and analysis need to be considered in the workflow.

- Schedule and timeline as well as logistics such as equipment, food, refreshments, and restrooms were also discussed. A list of remaining questions surrounding these topics was generated.

### *2.17.4 Train Derailment Workshop Follow-Up Activities, If Applicable*

After the workshop, several follow-up activities were carried out by UVM, including:

- Scheduled the next workshop with all involved groups.
- Contacted USAR VT-TF1 about involvement in the train derailment exercise to carry out SAR operations.
- Contacted the Burlington Department of Parks, Recreation, and Waterfront about conducting the exercise at the desired location, as they own/manage the land. UVM has carried out UAS operations for the department before and has an established relationship, which would allow for easy communication regarding permission to use area.
- Investigated software capabilities and options for airspace partitioning and visualization, keeping in mind the desire for an easy and accessible application.
- Prepared a visual of airspace coordination during the event to add planning materials and provide to the Air Boss. It was acknowledged that in a real-world emergency, this partitioning of airspace might not be established until operators arrive on the scene. For safe and efficient operations during the mock exercise, it was decided to generate this ahead of time.
- Continued to internally work out logistics of the exercise such as refreshments, restroom access, signage for the public, etc. Although less related to the actual flight operations, these details were crucial to consider for hosting a successful event.

### *2.17.5 Lessons Learned from the Train Derailment Workshop, Including Responses to Research Questions*

#### 2.17.5.1 Train Derailment Workshop Key findings:

1. During an emergency, a variety of platform and sensor capabilities may be necessary to collect the needed data. For an effective response, UAS teams in a region should respond according to their capabilities and expertise.
2. An ongoing livestream for situational awareness would provide feedback to an EOC, stakeholders, or other parties that are not physically at the scene to improve decision making. Not every platform has an option for livestream, though, and software solutions may be pricy, creating a need for a simple solution.
3. If there is limited time to collect UAS data, it may be necessary to prioritize data collection based on the immediate priorities as tasked by an EOC or within ICS.
4. During a train derailment, a live thermal feed providing insight into fires, locations of people, or related subjects may be more useful than thermal mapping, which requires time for processing and dissemination.
5. A platform that is approved to operate over people can expand emergency response capabilities by allowing for flight in more populated areas.
6. There are groups and organizations not directly involved in UAS operations that could find value in coordinating with UAS teams and helping to generate protocols.
7. During an emergency, UAS teams should be aware of the possibility of external and unexpected UAS or other aircraft to be in the area.

8. There is a need to safely coordinate airspace and track multiple UAS operations at once using an easy and accessible method or application.
9. Data dissemination and analysis are a crucial step in emergency response and need to be considered when planning UAS operations.
10. UAS operators should be aware and prepared to encounter unexpected sUAS that are not taking part in the response operations.

#### 2.17.5.2 Train Derailment Workshop Recommendations:

- UAS teams should be in communication about their platform/sensor capabilities and expertise and be aware of the data they can collect to fill gaps to carry out more effective emergency response.
- Research and test different UAS livestream functionalities to find a solution that is quick to set up and easily accessible to pilots and end-users alike.
- Before beginning an operation, ensure UAS teams are aware of the data priorities as tasked by the EOC or within ICS. In case there are complications or timing issues, the most important data should be prioritized over secondary collections.
- Develop protocols for which types of collections (mapping vs. real-time data) would be useful depending on the situation.
- During incidents, consider using a platform that OOP-compliant to expand access, improve safety, and collect more data.
- Make connections with groups and organizations throughout the region, even if they are not directly involved in UAS operations, as they may have valuable insight or suggestions for how to best integrate UAS into emergency response.
- To mitigate the risk of interference with other unexpected aircraft (manned and sUAS) in the operation area, consider what roles or procedures may be needed, such as designating a VO to solely scan the airspace.
- Research and test applications and methods for safely coordinating airspace and tracking multiple UAS operations at once, taking note of ease of use and accessibility.
- Further develop best procedures for easy processing and sharing of UAS data during or directly following an emergency response.

#### 2.17.5.3 Train Derailment Workshop Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. N/A
2. The UVM UAS team communicated with Burlington Parks, Recreation, and Waterfront for permission to operate in the area and had valuable conversations regarding the scope of the flights, safety procedures in place, and methods for keeping non-participants out of the area.

   UVM Emergency Management and Vermont Emergency Management provided valuable insight into the logistics behind emergency response mobilization, what to expect on scene and common challenges that arise during these types of events. This bridged the gap between technical UAS operations and the overarching risk involved in disaster operations.

3. There is a recreational path adjacent to the proposed flight area, posing a risk for the presence of non-participants. Some methods for mitigating this include:

- Planning the automated flight paths to stay within the designated area that does not overlap with recreation path.
- Adding a geo-barrier to the platforms so they cannot cross over the recreational path.
- Physically blocking off the entrance to the path that leads into the flight area to prevent the public from wandering in.
- Posting signage that notifies the public of the UAS operations in the vicinity.
- Having designated liaisons posted around the flight area along the recreational path to answer questions from the public or redirect if needed.
- Having additional VOs with the sole task of spotting non-participants that may enter the flight area and communicate this information to the Remote Pilot In Command (RPIC) for mitigation.
- Using an OOP-compliant sUAS platform.

A risk in this scenario was operating within Class C airspace and in vicinity to manned aircraft. This could be mitigated by:

- Deploying VO(s) to support RPIC in monitoring airspace.
- Utilizing ADS-B receivers for situational awareness.
- Monitoring airband radio scanner to be aware of communications on CTAF/UNICOM in vicinity.
- Identifying and being prepared to execute emergency procedures to yield ROW during the flight.

4. N/A
5. N/A
6. A multirotor platform will allow for hovering and easy manual flight to perform a variety of tasks including:
    - Hovering in place to provide a constant live stream of the scene
    - Maneuvering around obstacles and hazards to capture photos and videos
    - Conduct SAR operations with the flexibility to hover or maneuver

    A UAS platform that is approved to operate over people will allow for collection in more populated areas.

    A UAS platform that can efficiently swap payloads will allow for increased flexibility in data collection and specialized data products such as thermal, multispectral, or LiDAR.

7. N/A
8. N/A
9. N/A
10. Guidance surrounding prioritization of data collection would be useful for UAS teams to better understand where and how to focus their efforts during a response. Although this would be dependent on the situation, it would be best practice for the EOC, ICS, or other tasking agency to provide this information as needed to guide UAS operations.
11. N/A

#### 2.17.5.4 Train Derailment Workshop Lessons Learned Summary:

With a variety of platform and sensor options, UAS teams should be able to succinctly define their capabilities to share with other UAS groups in the region, relevant agencies, or the EOC/ICS during an emergency, allowing for more effective tasking and prioritization of data collection. During a response, it is important to determine if real-time monitoring, mapping, or some combination is required; examples of mission profiles for a train derailment could include a live stream feed, SAR operation, and EO, multispectral, and LiDAR mapping. It is crucial to mitigate risk during these operations by using VOs, coordinating and partitioning air space, and avoiding non-participants unless operating an OOP-compliant UAS.

## 2.18 5/19/2023, Drill, Airport Terrorism, Huntsville, AL, Conducted by UAH

This drill is a continuation of the Seminar event held on May 17, 2023, so the scenario is identical. See section 2.16.

### *2.18.1 Objectives of the Airport Terrorism Drill*

The Airport Terrorism drill was hosted as a repetitive tabletop exercise with local law enforcement and airport operations employees from Huntsville, AL. The main objective of this drill was to step through a real-world scenario of UAS incursion on active airspace during a special event and to elicit feedback from participants on how the use of other UAS assets may help alleviate the threat.

### *2.18.2 Planning for and Logistics of the Airport Terrorism Drill*

This drill was hosted on the last day of the “2023 Future Proof UAS & C-UAS Summit” which was a three-day event focused on showcasing the current technology for C-UAS and low-altitude airspace management. Over 250 attendees were present at the symposium mostly from local/state/federal government agencies and industry involved in UAS/C-UAS development. The ASSURE seminar on Airport Terrorism was advertised daily at the Future Proof Summit and took advantage of the existing event infrastructure, for instance, an event tent, temporary restrooms, and televisions, to host the drill.

### *2.18.3 Airport Terrorism Drill Execution*

The drill was conducted in Huntsville at the UAS/Counter-UAS Test Facility west of HSV. The drill was conducted under a large tent that had been erected for the previous days’ Future Proof event, providing a comfortable shaded location for the drill.

The drill coordinator explained the relationship between this drill and the seminar that had been conducted on 17 May at HSV, and explained the scenario accordingly.

The initial setup was shown graphically, with a map of HSV highlighted with the locations of public viewing areas (bleachers) and a VIP tent. The location and direction of the incoming Dream Chaser is indicated, as well as the location of emergency response vehicles, equipment, and personnel. This graphical depiction was printed at large scale on a 40’ x 60” foam board poster that was laid on some tables surrounded by participants. Colored pins were used to represent various vehicles, response groups, traffic indicators, and physical constructs. Since this was a drill, the map was cleared several times during the event and repopulated with pins as various Injects were inserted into the ever-evolving scenario.

There were two drill attendees, both members of the Huntsville Civic organization. They were:

Chad Tillman (Director UAS Operations for Huntsville City), and Joshua Shubert (HPD Law Enforcement Officer). Both had considerable experience operating UAS in the exact kind of environment represented in the drill. In spite of there being only two attendees. Discussion and critique were spirited and varied.

Seminar participants were prompted: "Discuss what is good and bad about this plan. What are some possible pitfalls? How would you change the arrangement? How might a nefarious actor take advantage of this layout?" As the discussion of these issues proceeded, additional prompts were introduced for discussion: "Does your organization have SOPs for UAS Operations? Does your organization have equipment preparation and maintenance checklists? Does your organization have airspace authorization processes? What information from the ICS would you expect before deployment?" They were also prompted to suggest the possible kinds of mishaps that might occur relating to drone usage during this event.

The drill discussion then moved into what might be called the "execution" phase, during which the emergency scenario unfolds. The scenario was identical to the one discussed in the seminar two days prior. As the instructor/facilitator described the unfolding events, he placed color-coded push pins into the layout image to identify specific locations of vehicles, groups, happenings, etc. This made it easier to recall and discuss specific details of the drill. He also imposed unforeseen "injects" into the script.

- Law enforcement and airport authority public safety subsequently respond to multiple unauthorized UAS spotted in the area.
- One response leads to an unauthorized UAS causing havoc to authorized UAS conducting safety monitoring missions, leading to a crash into the public viewing area.
- An unauthorized quadcopter falls into the bleachers, injuring two people, one severely.
- Another unauthorized UAS is successfully countered but causes a small battery fire in the field adjacent to the AOA, ¼ mile behind the observation bleachers.

During this portion of the drill, the guided conversation focused on possible responses and how the initial layout of resources might have been improved upon. Also, additional questions elicited responses relating to the organizations of the participants: "Has your organization responded to Airport or Public Event incidents in the past? In what capacity?"

As a final point for discussion during the drill, the participants were offered suggestions for ways in which UAS might have been used proactively in this scenario and invited to comment on the pros and cons of each suggested use.

#### *2.18.4 Airport Terrorism Drill Follow-Up Activities, If Applicable*

Follow up included further demonstrations of C-UAS technologies and engagement with local law enforcement developing drone first responder capabilities.

### *2.18.5 Lessons Learned from the Airport Terrorism Drill, Including Responses to Research Questions*

#### 2.18.5.1 Airport Terrorism Drill Key findings:

At the conclusion of a lengthy discussion of the various paths by which the drill might have unfolded, the following Lessons Learned were discussed:

1. Prior to this event, a more thorough evaluation of the site, engaging the participation of varied first responders, would have produced a far more robust strategy. Response vehicles would have been dispersed over a broad area for rapid response in several likely locations. The positioning of observers and VIPs might have been moved to safer locations, and traffic flow would have been evaluated, redefined, and better controlled, for example.
2. Advance planning for crowd and traffic management is particularly important to a public event of the sort described in this scenario. A lockdown of the entire area of concern should have been imposed well in advance of the landing date.
3. With regard to previous historical airport attacks, there is little that UAS might have done to prevent the incident or even to have given significant advance warning of the impending action.
4. A persistent overhead observer drone might be effective in retracing the path(s) of perpetrators' vehicles useful for reconstruction and forensic analysis of the incident. This, of course, is complicated by privacy issues when conducting persistent surveillance.
5. Post-event, drones are useful for damage assessment, search & rescue, avoiding the personnel hazards of secondary detonations and chemical hazards.
6. Over the long term after an event that involves infrastructure damage, drones are of value in inspection and damage assessment, avoiding the hazard of placing humans in the midst of unstable structures.

#### 2.18.5.2 Airport Terrorism Drill Recommendations:

(Extracted directly from drill participant discussion topics):

- HPD has a common frequency, but their radios are labeled differently. The need exists for consistent equipment labeling practices.
- 1.5 hours before Dream Chaser landing:
    - 3 days before, begin flagging parking areas on County Line Road, as well as areas on Boeing Blvd.
    - Need controlling element at entrances to roads that have parking.
    - "Cascading chaos" if we only have one entrance and exit. (Backup down Interstate 565)
    - Get word out early that traffic on the day of event is going to be bad. Bring in HPD traffic services to help control the flow of traffic. Public relations are necessary as well.
    - Get traffic off the roads. Maybe use busses to move people from off-site parking. (Helps preclude vehicle-borne IEDs)
    - Define jurisdiction lines. Are we dealing with HSV or Madison County jurisdiction?
    - VIP center is blocked in, there's no emergency exit or way to get emergency vehicles in.
    - Move the VIP tent to the emergency responders' box. Splits people up and keeps them away from the crowd. Also eases the burden on response teams. Or could possibly move tent further south.

- Add some cameras around the area with remote viewing areas.
- Put an additional emergency response team next to the bleachers. (Ask Huntsville Hospital or nursing students to assist in the medical tent) (Reach out to other cities to help provide ambulances)
- Alabama Law Enforcement Agency (ALEA) takes lead.
- Liaison from each agency to help communication.
- Since it’s private industry, this will be an FBI and FAA managed situation. NASA is probably going to want to be engaged as well.
- FAA is the ultimate authority for this event. It will be crucial to establish roles and responsibilities early.

- Use of UAS before an event:
  - Have one on each fence line monitoring perimeter.
  - UAS won't prevent unauthorized UAS usage but will help find pilots.
  - Reach out to people with active tracking systems like Observation Without Limits (O.W.L.) ™ to help find UAS in the air.
  - Threats from agriculture sprayer?
  - Huge threat from fentanyl since so little is needed to kill so many (Small payload)
  - 50 miles out - ground all UAS in the air.
- Drone in air:
  - Have we posted signs saying no drones in the area?
  - Post signs “Any drones in the air will be confiscated”!
  - No packages allowed at or beyond security checkpoints.
  - If we have proper checkpoints drone pilots are going to be restricted to distant parking lots.
  - Is it coming from the river? Proximity of Tennessee River demands extra vigilance to the south.
  - Add game wardens to the list of people that should participate due to proximity of Wheeler Wildlife Refuge.
  - Use Leidos systems to bring drones down. (Would need special permission but it’s possible.)
  - 10 minutes from landing everything allowed is on the ground.
  - Can’t use a helicopter because of the TFR.
  - Reserve airspace for all counter UAS operations.
  - Issues to consider if eliminating nefarious drone: Where do we bring it down? Does it have explosives on it?
- Drone comes down and injures someone:
  - Bring in a smaller (rather than larger) group in order to limit the amount of panic.
  - Assume there is an explosive on the drone. Nobody moves in until Explosive Ordnance Disposal (EOD) team clears the area.
  - Name parking lots and have aisles so that we can communicate pilot locations.
  - Ensure declaration of “Intent to fly.”
  - By nature, DJI aircraft will not be able to fly in the airport airspace. Looking for First Person View pilots that are more likely to be flying.
  - Concern: Where does liability fall if we take control of the drone and then it crashes?

    - Put up temporary telescoping cameras to watch parking areas during 10 minutes that drones can't be in the sky.
    - Air Boss will be monitoring two channels. One helping get people out, one for Emergency Medical Services situational awareness.
    - Aid station is the staging point until we can get an ambulance involved.
- Fire in the hay field behind the audience:
    - Employ nearest fire truck to contain blaze.
    - The ambulance will drive through the smoke.
    - Keep all parking off county line road to let ambulance in and out.
    - Need containment to keep people from running onto runway when they are moving away from the smoke.
    - The best method to prevent all of this is to prevent drones from getting into the air.
    - Have vendors selling water equipped with fire extinguishers.
    - Have multiple brush trucks available and create fire lanes.
    - Use all the counter-UAS systems from future proof to mitigate risk.
    - Look for heat signatures in the nearby woods.
- Each agency knows its roles and responsibilities and when they take over:
    - Someone at the command hub is deciding which agency takes over and when.
    - Have a round table IN PERSON with all the players similar to today's drill.
    - Is the FAA or NASA going to have their own resources to map in the event of a crash. We will have to deconflict airspace.
- There are going to be a lot of cameras at this event.
- Whenever systems take over control of UAS, take over control when it's not over people.
- Park people on the other side of the airport and require a shuttle over to the bleachers.
- Have bomb dogs sniffing cars.
- Still put drones on the corners of the event.
- Parking is available at Dunlop and Remington plants.
- Posted officers near bleachers, patrolling parking, and on roads for traffic management.
- When drone is in the air what do we do?
    - Utilize counter UAS devices.
- Mitigated poorly and comes down in bleachers to cause an injury-
    - Get HEMSI on their way.
    - Move patient to the nearby aid station.
    - The officer on county line road opens it up for an ambulance.
- Move the crowd back to the west of county line road.
    - Emergency crews can move in front of the crowd. Need to keep people out of the road.
- Terrorist attack to run a barricade:
    - Need to keep people off road in this scenario.
    - Utilize serpentine access points on entrances.
- Deter, Deny, Delay:
    - Put food trucks on the road to help block road off.
    - Possibly bring food trucks behind the crowd.
- Move aid station up the road closer to crowd. And put another one near parking.

- People can park at the airport too, but they will need to be shuttled to viewing.
- Wind pushes fire across the road:
    - Brush trucks handle this.
    - Can Redstone Arsenal FD help supplement fire response?
- Outsource some of the screening to lighten the load on Huntsville Police Department (HPD)
- What happens if kids are there on school field trips?
    - Set special bleachers for the kids to help keep them contained.
    - Required to register to find out how many kids will be there.
    - Maybe put them outside of the terminal on inside of the fence so they can be controlled.

#### 2.18.5.3 Airport Terrorism Drill Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. For the Airport Terrorism event drill, the participants identified several different use cases for which UAS are particularly well suited:
    - Traffic monitoring
    - Transporting of medical supplies in a highly congested environment
    - Large scale event situational awareness
2. For the Airport Terrorism event drill, the Huntsville local law enforcement was extremely engaged in discussing a strategy and solution to a potentially real-world scenario. Some of the lessons learned were the level of effort required for preparatory success in managing traffic of both people and automobiles, sterilizing the airspace at a pre-determined time before the event takes place, and having a method of UAS mitigation that ensured protection of spectators.
3. The A52 drill participants responded with a suggestion of reducing the use of UAS at time of event. This was surprising to hear until their justification of being able to rapidly identify a UAS flight violation in what would effectively be airspace with a TFR in place. This rapid ID would allow the law enforcement team to quickly decide best practices for effectively disabling the aircraft or identifying the PIC of the craft and to respond appropriately.
4. *Traffic monitoring:* Use sUAS in areas of heavy traffic on the day of the event to inform law enforcement when the need arises to redirect traffic or take other measures to improve/control traffic flow. Mitigation – avoid flying over people or traffic, use qualified Part 107 trained UAS PIC to maintain proper flight procedures for the situation.

    *Transporting of medical supplies in a highly congested environment:* Use sUAS to deliver medical supplies in an extremely congested environment with restricted traffic flow. Medical supplies (Whole blood, plasma, or medication) are flown from the central medical facility (near the center of the airfield) to the point of need (most likely in the crowded spectator area). Mitigation – minimize flying over people or traffic, use qualified Part 107 trained UAS PIC to maintain proper flight procedures for the situation. Land the UAS in an unoccupied area nearest to point of need. Qualified emergency management agency personnel, stationed in many food trucks, will arrive on scene rapidly enough to direct PIC in landing of UAS.

5. All CONOPs defined in this drill would employ sUAS, typically commercial multicopters.
6. All CONOPs defined in this drill would employ sUAS, capable of carrying video equipment of high resolution and sufficient battery power to remain airborne for up to an hour. At least one sUAS must have sufficient lifting capability to transport medical supplies up to and

included blood bags. One unit of blood weighs 1.04 lbs. Because the equipment may unavoidably fly over people, proven reliability is also needed.

7. N/A
8. N/A
9. N/A
10. It became evident that planning must begin months in advance for an event of this magnitude and complexity. Elements such as remote parking, traffic management, site layout, and logistics must be carefully planned and synchronized. When conducting this planning, it is useful to brainstorm in an attempt to conceive of every imaginable nefarious activity that might be encountered and how it might be prevented, thwarted, or minimized. A planning checklist for large public events in a time of drones would be a valuable asset in conducting this long-range planning.
11. N/A

#### 2.18.5.4 Airport Terrorism Drill Lessons Learned Summary:

Advanced planning is crucial for an event of this magnitude and complexity, especially for details like remote parking, traffic management, site layout, and logistics. When conducting this planning, it is important to try to be cognizant of every imaginable nefarious activity that might be encountered, so to prepare for how it might be prevented. A planning checklist should be created before a large public event like this.

## 2.19 6/21/2023, Workshop/Tabletop, Train Derailment, Burlington, VT and Online, Conducted by UVM

The third workshop was conducted in-person and virtually. With the exercise location selected, the topics discussed during this workshop focused on associated risks and hazards, airspace considerations, and finalization of UAS teams and additional roles. The attendees included UVM, VTrans, UVM Emergency Management, and Vermont USAR VT-TF1.

### *2.19.1 Objectives of the Train Derailment Workshop*

The objectives of this meeting were to further solidify logistics for the exercise, including roles and responsibilities for flight teams and airspace deconfliction. Additionally, this meeting discussed risk mitigation techniques for the area and the necessary actions to ensure safety amongst participants and the public.

### *2.19.2 Planning for and Logistics of the Train Derailment Workshop*

This train derailment workshop was planned at the conclusion of the previous event, with UVM finalizing a date and sending out a Microsoft Teams invite for virtual participation and reserving a room on UVM's campus for in-person attendance. Discussion topics to consider as a group were noted prior to the start of the meeting, which were based on conversation and remaining questions from the previous meeting. To provide more insight into the exercise location, the UVM Team visited the site ahead of the meeting, captured photos (Figure 13, Figure 14), and took note of important considerations.

Figure 13. Entrance to the site location on the right, adjacent to the rail tracks. Recreation path is to the left.

Figure 14. Stationary train cars present on the site.

### *2.19.3 Train Derailment Workshop Execution*

UVM presented information via PowerPoint. Throughout the presentation, open discussion was held amongst participants to provide valuable insights and address concerns. Following the presentation, conversations expanded on these topics and other relevant considerations. A variety of topics were discussed to continue planning out logistics of the mock exercise including, but not limited to:

- Burlington Vermont Waterfront (**Error! Reference source not found.**) along the Vermont Rail Systems railway (**Error! Reference source not found.**) is the decided location of the exercise. The site has train cars to replicate what might be present during an emergency, nearby non-participants that must be mitigated, and controlled airspace requiring authorization, all of which will help participants practice necessary procedures for UAS operations. Efforts will be made to ensure the public are kept out of the operating area and aware that the event is a mock exercise and not an active emergency.


Figure 15. Blue arrow indicates the site location in relation to the city of Burlington.

Figure 16. A closer look at the site location, which is along the railroad tracks offset from the recreation path.

- Risks identified for the location include power lines that should be avoided during flight, potential for non-participants to be recreating in the area, and varying topography that should be considered when flight planning (Figure 17).

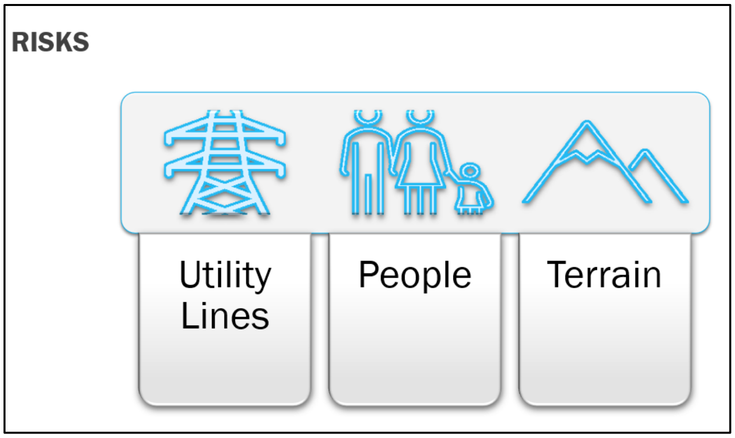


Figure 17. Identified risks include utility lines, people, and terrain.

- The exercise location is within Class C airspace, due to its proximity to the Burlington International Airport (BTV). The location falls within a 400-foot LAANC cell (Figure 18). It was determined that LAANC approvals will be obtained prior to flight operations by each UAS team to allow for flights up to the maximum of 400 feet in the designated area of interest.

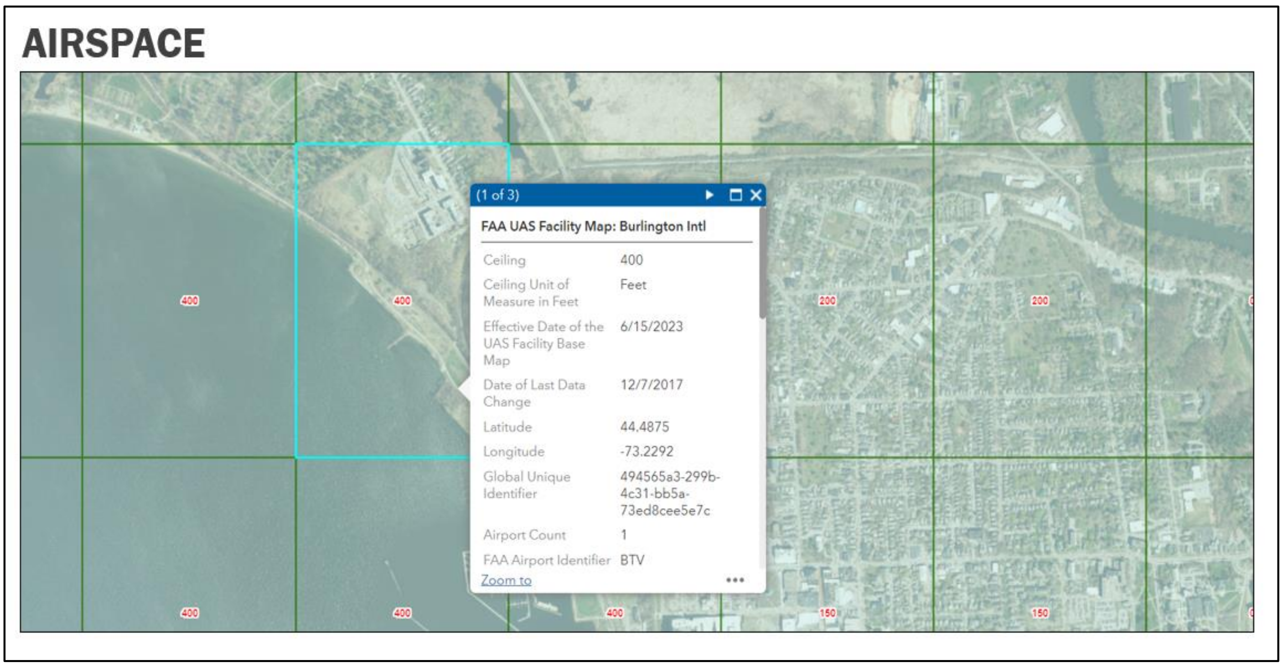



Figure 18. The LAANC cell for the site is selected, revealing a ceiling height of 400ft.

- The UAS operators for the exercise are UVM, VTrans, and USAR. Each organization will operate their own individual sUAS platforms and sensors to help accomplish the goals of the mock train derailment response. The following are additional attendees that will not be operating platforms but plan to remain involved for observation and/or evaluating performance: Burlington Police Department, Vermont Emergency Management, and UVM Emergency Management.
- The mission profiles were finalized for each group as well as the associated roles/responsibilities for each team.

- It was decided that identification of the following mock hazards would suit a train derailment: Fire, Spill, SAR, and after-action investigation (Figure 19).
  - Fire will be identified using real-time EO (RGB) and thermal imaging
  - Chemical spill by EO (RGB) and multi-spectral orthomosaic
  - SAR using EO (RGB)
  - After-action investigations data collected with EO (RGB) Orthomosaic and terrain models.

**MISSION PROFILES**

| Situation | Need | Platform & Sensor |
|---|---|---|
| Fire | Real-time RGB and thermal imaging | Multi-rotor with RGB and thermal sensors |
| Spill | Real-time RGB<br>Multispectral orthos | Multi-rotor with RGB<br>Fixed-wing multispectral |
| SAR | Real-time RGB | Multi-rotor with RGB |
| Investigation | RGB orthos<br>Terrain Models | Fixed-wing orthos<br>Multi-rotor LiDAR |

Figure 19. Mission Profiles for the mock exercise.

- The scenario will be logistically planned by UVM, the Air Boss will be a representative from the VTrans, evaluation of the event will be conducted by Kansas State University (KSU), data will be processed by UVM, and data will be disseminated by UVM and VCGI (Figure 20).

**ROLES & RESPONSIBILITIES**

| Role | Organization |
|---|---|
| Scenario | UVM |
| Air Boss | VTrans |
| Evaluation | KSU |
| Data Processing | UVM |
| Data Dissemination | UVM/VCGI |

Figure 20. Exercise roles assigned to participanting organizations.

#### *2.19.4 Train Derailment Workshop Follow-Up Activities, If Applicable*

The primary follow-up activity was for UVM to finalize the schedule and documentation for the functional exercise, planned to occur in August 2023. However, the severe impacts from major flooding that occurred throughout Vermont in July and August 2023 resulted in the SAL Director postponing the planned exercise event until the winter/spring of 2024.

### *2.19.5 Lessons Learned from the Train Derailment Workshop, Including Responses to Research Questions*

#### 2.19.5.1 Train Derailment Workshop Key findings:

1. Non-participants and other public in the vicinity of UAS flight operations often have curiosity and questions that can be distracting to UAS pilots or otherwise disruptive to the safety of flights.
2. UAS pilots should be aware of how to submit airspace approval requests through typical pathways as well as during an emergency. When applicable, LAANC can be a quick and straightforward method.
3. When conducting an exercise or real-world flight operations, there are often issues, challenges, unexpected technical problems, or other lessons learned that arise.
4. Expected mission profiles were confirmed for a train derailment situation:
    - Real-time fire response: multirotor with EO/IR capabilities
    - Oil or hazmat spill: Multirotor with EO sensor & fixed wing with multispectral sensor
    - Search & Rescue: Multirotor with EO sensor
    - Investigation & Reconstruction: Fixed-wing with EO mapping sensor, multirotor with LiDAR sensor

#### 2.19.5.2 Train Derailment Workshop Recommendations:

- Develop methods for limiting interruptions from the public, such as:
    - Designating a liaison who can communicate with the public during operations to prevent distraction of pilots or observers.
    - Creating signage, leaflets, and/or digital outreach to inform the public on the operations.
    - Physically blocking off access to the flight area if permissible.
    - Ensuring RPICs are wearing hi-visibility vests identifying them as sUAS operators.
- During an emergency, check airspace restrictions prior to arrival to muster point deployment if possible. If applicable, LAANC should be used to acquire airspace authorization instantly and expedite operations. For more complicated methods such as SGI, consider generating an SOP for types of airspace approval, how to request authorization depending on the scenario, and resources for doing so.
- Develop a method for tracking challenges or other lessons learned during an exercise or real event such as:
    - Designating someone who will take notes as issues arise.
    - Hosting a hotwash afterwards and recording notes.
    - Conducting a debrief meeting in the following days, or a follow-up over the next weeks.
- Integrate the feedback and solutions captured during the above activities into action as soon as is feasible.

#### 2.19.5.3 Train Derailment Workshop Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. UAS can be used for real-time monitoring and live stream capabilities, strategical operations such as SAR, and technical analysis resulting from mapping products. Most of these use cases

would not be possible for boots on the ground during an active, potentially hazardous or dangerous train derailment.

While live stream feed can be ingested by the ICS or EOC in real time, the resulting UAS products from mapping could be used for further analysis, damage assessment, or research.

2. UVM, VTrans, and USAR VT-TF1 discussed capabilities, internal procedures, best practices and suggestions, and other insightful knowledge to generate mission profiles that best fit their capabilities and addressed the challenge at hand.

   The VTrans UAS Program Manager will serve as UAS Air Boss, enabling communication between agencies and ensuring successful coordination, which otherwise would not be possible between each team.

   KSU will serve as an evaluator and track lessons learned, assisting in the process of reviewing and refining procedures, which is a crucial step in facilitating safe UAS operations.
3. The issue of airspace and flight over non-participants has been discussed and previously mentioned mitigation techniques have been further developed. Another common risk identified for the location include obstacles such as trees and power lines:
   - Utilize available obstacle avoidance capabilities for UAS that have the functionality, which will allow the platform to stop before encountering obstacles.
   - Utilize VOs to keep an eye on the platform and warn pilot if it nears obstacles, which can be especially helpful for powerlines or thin branches that are often not detected by obstacle avoidance features.

   An additional risk is the varying topography of the landscape, which slopes upwards near the railroad tracks.
   - A mitigation technique is to ensure any automated flight plans utilize elevation data/terrain following to ensure consistent altitude above ground through changes in the landscape.
4. N/A
5. The following categories:
   - Real-time fire response: multirotor with EO/IR capabilities
   - Oil or hazmat spill: Multirotor with EO sensor & fixed-wing with multispectral sensor
   - SAR: Multirotor with EO sensor
   - Investigation and Reconstruction: Fixed-wing with EO mapping sensor, multirotor with LiDAR sensor
6. N/A
7. N/A
8. N/A
9. N/A
10. N/A
11. The following hazards/disasters and scale:
    - In this scenario, UAS would be beneficial to provide a higher-resolution, ongoing livestream of the scene. With the capability to hover at relatively low altitudes, move in closer to investigate features of interest, and provide either EO or IR data, a

multirotor UAS could more effectively provide detailed information and context of the scene that would be challenging with a larger manned flight.

- If the emergency is localized, as may be the case with a train derailment, SAR operations could be more focused with a UAS that can navigate at a range of altitudes and reach otherwise inaccessible locations that are not feasible for a larger manned aircraft.
- The precision of a smaller UAS sensor as opposed to a manned flight would also aid in identification of fires, hazardous materials, or other features that could be difficult to see at a higher altitude.

#### 2.19.5.4 Train Derailment Workshop Lessons Learned Summary:

UAS pilots should be aware of the process for checking airspace and gaining approval, LAANC being a crucial capability to take advantage of. It is important to be aware of non-participants in the area and consider using a variety of methods including signage and/or a liaison to prevent non-participants from entering the flight area and distracting UAS operators or crew members. For a train derailment scenario, a combination of mission profiles will likely be needed to capture the data, so it is best to get support from those with the proper capabilities and bring a variety of platforms and sensors when possible.

## 2.20 6/28/2023, Functional Exercise, Hurricane/Tornado/Flooding, Tallahassee, FL, Conducted by UAH

The CURSE was a large-scale functional exercise involving 63 agencies from across the southeast region involved in disaster response. Running from 28-29 June 2023, CURSE consisted of two full days of field operations performing real-world tasks for UAS strike teams. These kinds of tasks included damage assessment, SAR, and mapping missions in locations across Tallahassee, FL. UAH pulled together two UAS strike teams consisting of at least one UAS mission pilot and one UAS technician to attend and participate in the functional exercise. The Leon County Public Safety Complex in Tallahassee, FL served as the EOC and hosted the FEMA Region IV Remote Sensing Cell.

### *2.20.1 Objectives of the Hurricane/Tornado/Flooding Functional Exercise*

CURSE was designed to bring together UAS operators and remote sensing expertise across a wide range of emergency management agencies. Teams were expected to conduct a series of real-world disaster response tasks and follow the ICS processes to property communicate and record activities.

### *2.20.2 Planning for and Logistics of the Hurricane/Tornado/Flooding Functional Exercise*

UAH prepared two strike teams to attend and participate in CURSE consisting of at least one mission pilot and one field technician.

### *2.20.3 Hurricane/Tornado/Flooding Functional Exercise Execution*

UAH teams drove from Huntsville, AL to Tallahassee with multiple UAS and supporting hardware to properly engage with the CURSE operational tasks. On the first day of operational tasks, the UAH teams operated independently. On the second day, the two UAH teams remained together to more effectively collect and process data to the remote sensing teams at the EOC.

### *2.20.4 Hurricane/Tornado/Flooding Functional Exercise Follow-Up Activities, If Applicable*

CURSE 2024, a follow-up to this CURSE event has already taken place as a tabletop exercise in which UAH participated.

### *2.20.5 Lessons Learned from the Hurricane/Tornado/Flooding Functional Exercise, Including Responses to Research Questions*

Covered in separate report covering Lessons Learned from Functional Exercises. Also, the following:

#### 2.20.5.1 Hurricane/Tornado/Flooding Functional Exercise Key findings:

1. Understanding of the circumstances surrounding the situation is of paramount importance to appropriate UAS selection.
2. Multi-crew deconfliction becomes a challenge during the fast-moving developments experienced in disaster response.
3. UAS familiarization: Crewmembers may not have a complete understanding of the UAS being flown.
4. Especially when operating with DJI aircraft, beware of unexpected GEO fencing locks.
5. When operating in extreme environmental conditions, be prepared for equipment malfunctions.
6. Overly complex communication practices can overwhelm small or inexperienced response teams and create a hindrance to good communication.
7. Especially with new or inexperienced crews, there may be a lack of knowledge or understanding of SGI/TFR.
8. Several crews observed during this exercise demonstrated a lack of knowledge or disregard for appropriate and applicable regulations.

#### 2.20.5.2 Hurricane/Tornado/Flooding Functional Exercise Recommendations:

- A visual observer or other liaison to coordinate with other crews on site can help solve the issue of multi-crew deconfliction.
- Ensure the crew has been trained and is proficient with the UAS being operated.
- Simplifying communication modes and limiting communications to only pertinent information would improve communication pitfalls,
- Wherever possible, disaster response personnel should be required to have completed thorough training in the regulatory framework that applies to their functions during the emergency.

#### 2.20.5.3 Hurricane/Tornado/Flooding Functional Exercise Informed Research Question(s):

1. N/A
2. FEMA and the other participants in the exercise conducted a thorough after-action review on the final day to ensure that each participant could share their lessons learned.
3. N/A
4. There were instances observed when crewmembers may not have a complete understanding of the UAS being flown. Audible warnings for battery depletion were misinterpreted for Return to Home initialization.

Ensure the crew has been trained and is proficient with the UAS being operated. Currency requirements for organizations could ensure knowledge recency and proficiency levels are appropriate for the missions.

5. N/A

6. One flight area required a custom unlock from DJI. This cannot be done from a phone, so it required the crew to utilize a laptop and go through the unlocking process.
   Recommendation: Utilize DJI's Qualified Entities Program. This unlocks all no-fly zones in the United States. While this is reserved for public safety entities, those who support these entities on missions also qualify. This removes the requirement to receive a custom unlock and allows crews flying DJI equipment to get in the air much quicker. The crew will not have insight on the area of operations until the request comes through, so, having the UAS unlocked for all No-Fly Zones (NFZ) locations would be ideal. It would also prove valuable to have a non-DJI UAS with similar capabilities on site in case of NFZ issues. RPICs should keep in mind that DJI unlocks do not replace an FAA airspace authorization, should one be required for the flight location.
   Some crews had equipment overheating and had to either move to shade or pause operations to cool the equipment down. Ambient temperatures were in the 105-degree Fahrenheit range.
   Recommendations: Finding a spot to set up in the shade or pause operations to allow the equipment to cool down worked well for crews. Ideally, BVLOS approvals to allow the RPIC to operate from within a climate-controlled vehicle would be best. Bringing shade devices, fans, and ice coolers can also help in these situations. Before deployment, crews should consider the environment and how to best mitigate the environmental hazards to themselves and their equipment

7. Teams arrived on mission sites without assessing task requirements. For example, during the first mission, the strike team acknowledged: "It worked out that the other crew did not take this mission. Their UAS would not have performed well." One team may have a better suited UAS for the tasking.

   Prior to deploying for a mission, if there are multiple strike teams, communicate task requirements (data to be collected, area to observe, takeoff/landing locations if available, etc.). Strike team capabilities knowledge may also be observed from the Incident Commander (IC), who would be able to assign tasks based on those capabilities.
   Recommend designating a Visual Observer or other liaison to coordinate with other crews on site. Being able to adjust as the situation progresses to accommodate other crews is essential. Therefore, having a plan in place prior to takeoff would be beneficial. For example, the safety brief could include alternate routes or altitudes to fly, depending on additional operators in the area. This would also be beneficial if new, arriving crews spread out so much that it becomes difficult to communicate with them.

8. N/A

9. N/A
10. There were multiple crews operating in one location at a time. UAH did a nice job coordinating with each other and with external crews, but that level of communication and separation was

not observed from external crews operating during the event. Additionally, as new teams arrived on scene, communication for deconflicting was non-existent.

Due to the communication methods for this particular exercise, it was difficult for many crews to keep up with the assigned tasks. At least three separate means for communicating between crews and the EOC were established. Smaller crews especially did not have the resources to dedicate someone to monitoring these methods continuously, and it was easy to miss communications.

Recommendations: Simplifying communication modes and limiting communications to only pertinent information would improve communication pitfalls. However, in a real-world situation, electronic communications may be limited as a result of the disaster. The focus then would be on inter-crew communication procedures and should be something that is addressed during the safety briefing with the crews.

While nearly all crews operated under 14 CFR Part 107 during the exercise, it would be helpful for crews to become familiar with operations within TFR and how to procure SGI approvals from the FAA.

Recommendations: Although SGI requests would not be approved for training scenarios, it would be beneficial for future training exercises to implement a mock “approval authority” for crews to run through the process. This would ensure that for real-world situations, crews would have the knowledge necessary to obtain emergency approvals.

Multiple crews were observed flying BVLOS of the RPIC. Some crews employed a Visual Observer (VO) in offset locations from the RPIC, under the impression that this would satisfy the requirements of 14 CFR Part 107.31. One crew failed to use a VO at all, and continued BVLOS of the RPIC throughout the entirety of the flight.

Recommendations: Ensure all crews are following the regulations by completing standardized trainings and briefings prior to the operation. Explore all possible avenues for legal operations- SGI, public COA if possible, operating under 14 CFR Part 107 waivers.

11. N/A

#### 2.20.5.4 Hurricane, Tornado, Flooding Use Case (CURSE) Lessons Learned Summary

In this live exercise, lessons emphasized the importance of matching UAS to tasks through better communication among teams and the EOC. Effective coordination among multiple UAS crews is crucial to avoid interference between strike teams and to ensure the UAS with the best capabilities is assigned to the tasks at hand. Comprehensive training and currency requirements are needed to prevent misinterpretations of assignments and responsibilities. Understanding of equipment limitations and planning for equipment cooling in hot environments is essential. Simplified communication methods and inter-crew communication are crucial for effective operations. Lastly, crews should be well-versed in the regulatory environment in which they are operating – 14 CFR Part 107 or Public COAs. Knowledge in obtaining SGI approvals and procedures for operations in TFR areas can greatly increase safety of the NAS while adhering to the regulatory environment. Practice of these operations should incorporate mock approval processes for SGI and TFR access.

## 2.21 7/11/2023, Functional Exercise, Flood Response, Montpelier, VT, Conducted by UVM

The State of Vermont was severely impacted by severe storms, flooding, landslides, and mudslides between July 7 – 21, 2023. The initial storm system on July 9-10 dropped between 6-9 inches of rain causing catastrophic flooding in many areas throughout the state. The storm, which initially struck New York before moving to New England, resulted in severe flooding that shut down major roads and highways and prompted hundreds of evacuations. Two major rivers, the Winooski and Lamoille, surpassed water level records set during 2011's Hurricane Irene. A disaster was declared by FEMA on July 14, 2023 (DR-4720-VT) following the Governor's July 13 request for an expedited major disaster declaration.

In coordination with Vermont Emergency Management, VTrans, and Vermont State Police, UVM's UAS Team began sustained sUAS flight operations to support response and recovery efforts on July 10, 2023, operations continued into late August. In total, more than 290 individual sUAS flights were carried out, with the final missions related to flood recovery efforts occurring in late October and early November 2023.

This functional exercise presents a set of sUAS flight operations on July 11$^{th}$, 2023, with the purpose of documenting high-water flood impacts in downtown Montpelier. This operation was selected as particularly illustrative of the variety of challenges and lessons learned throughout more than 86 fixed-wing and multirotor orthoimagery mapping operations, in addition to 94 small multirotor missions for oblique image and video capture.

### *2.21.1 Objectives of the Flood Response Functional Exercise*

The purpose of this operation was to acquire UAS imagery and mapping data to visualize the flooding extent, provide situational awareness for potential rescue efforts, support rapid Geospatial Damage Assessments (GDA), provide documentation to support a request for a federal disaster declaration, and to aid in future flood resiliency research and planning. Montpelier was identified by the Vermont SEOC as a high-priority location for data collection on July 11 due to the severity of flooding damage, the city's dense population, and geographical location. Given the dense population compared to many parts of a rural state, data collection of this area would provide further insight into the impact of flooding on urban areas and residents, maximizing the impact of the work being done. At the time of this mission, a dam located upstream from Montpelier was at risk of overflowing and given that the downtown area was already inundated, it was crucial to capture high-resolution spatial data of the city as quickly as possible.

### 2.21.2 *Planning for and Logistics of the Flood Response Functional Exercise*

Initial planning for this operation began on the morning of July 10, 2023, as Vermont began to realize the severity of the impacts of initial overnight July 9-10 storms. The Director of the UVM SAL created a new communications channel in Slack, the lab's internal communication software system, to focus on response to this flood event. Throughout July 10, meetings occurred for the UAS team to deploy UAS response teams, assign mission priorities, allocate resources, and prepare equipment for anticipated operations. Initially, the response teams were generated to carry out the following mission profiles and equipment allocations. This exercise report focuses on the efforts of the team capable of OOP-compliant large area mapping operations.

- Large area true-color mapping with OOP capacity. Secondary profile – capture of oblique imagery and video.

- AgEagle (senseFly) eBee X and eBee TAC fixed-wing UAS
    - senseFly SODA true-color mapping sensor (OOP compliant)
    - senseFly SODA 3D true-color mapping sensor with oblique capabilities (OOP compliant)
    - senseFly Aeria X true-color mapping sensor
    - senseFly Duet-T true-color and thermal mapping sensor
  - DJI Mini 3 Pro multirotor
- Medium/small area true-color mapping and 3D modeling with focus on infrastructure, landslides, small communities. Secondary profile – capture of oblique imagery and video.
  - DJI M300 multirotor UAS (2 systems)
    - DJI Zenmuse H20T EO/IR sensor
    - DJI P1 true-color mapping sensor
    - Yellowscan Surveyor LiDAR sensor
  - DJI Mini 3 Pro multirotor
- Imagery/video collection. Secondary profile – small area true-color mapping.
  - DJI Mavic 3
  - DJI Mini 3 Pro
  - DJI Mavic 3 Multispectral

Additional internal coordination occurred to identify priority locations and the expected timing of peak flood water levels, which were anticipated to be around 12:00 EDT on July 11. Following the SAL Director and UAS Team members attending a FEMA Region 1 Federal Emergency Function partners activation call at 10:45 EDT on July 10, outreach efforts to offer UAS support to impacted communities across the state were undertaken by email, listserv, and by phone calls with agencies and contacts across the state. Additional coordination through text messages with the UAS Program Manager at VTrans continued through this period to assist in identifying priority locations. During the afternoon of July 10, internal meetings with the UVM UAS Team were held to confirm tasking request for mapping of downtown Montpelier as soon as feasible, ideally to align with the expected peak flood conditions of the Winooski River on July 11.

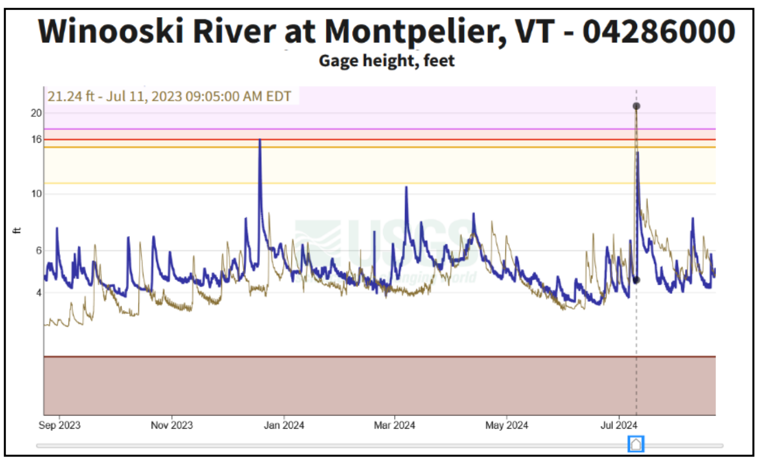



Figure 21. Winooski River guage height exceeding record flood stage at 21.24ft at 0900 EDT on July 11, 2023.

The flight crew assigned to this operation began with a review of the anticipated flight area and surrounding airspace in the late afternoon of July 10. Montpelier is the capital city of Vermont and is in Class E airspace due to its proximity to Edward F. Knapp State Airport (MPV) as displayed in Figure 22. The intended flight area in downtown Montpelier was restricted to LAANC approval up to 200 feet AGL (Figure 23). To maintain VLOS of the UAS and maximize mapping efficiency, the UAS crew were determined to receive approvals to operate at or below 400ft AGL. It was determined that the request for this airspace authorization should be submitted through the SGI process, rather than an Airspace Authorization through FAA Drone Zone. A UAS Technician was tasked with preparing a SGI request for operations at approximately 17:30 EDT on July 10. The UAS Team Lead reviewed the request, added additional UVM personnel to the list of pilots/observers, and increased the requested flight radius to 0.75NM. The SGI request was submitted to the FAA System Operations Support Center (SOSC) at 18:53 EDT on July 10 by email. Staff at the SOSC replied by email at 1911 EDT, requesting a statement of work from VTrans on agency letterhead stating that they were enlisting the services of UVM. The SAL Director replied at 19:18 EDT, copying the UAS Program Manager at VTrans and providing details about UVM’s role within ASSURE, with emphasis that a significant part of research objectives in A52 was to respond to disasters with UAS. A COA was issued at 16:51 EDT by the SOSC, with a note to carry out calls prior to lift and upon completion of operations at each site to Boston Air Route Traffic Control Center (ARTCC) (ZBW) so they could issue advisories to manned traffic in the area.

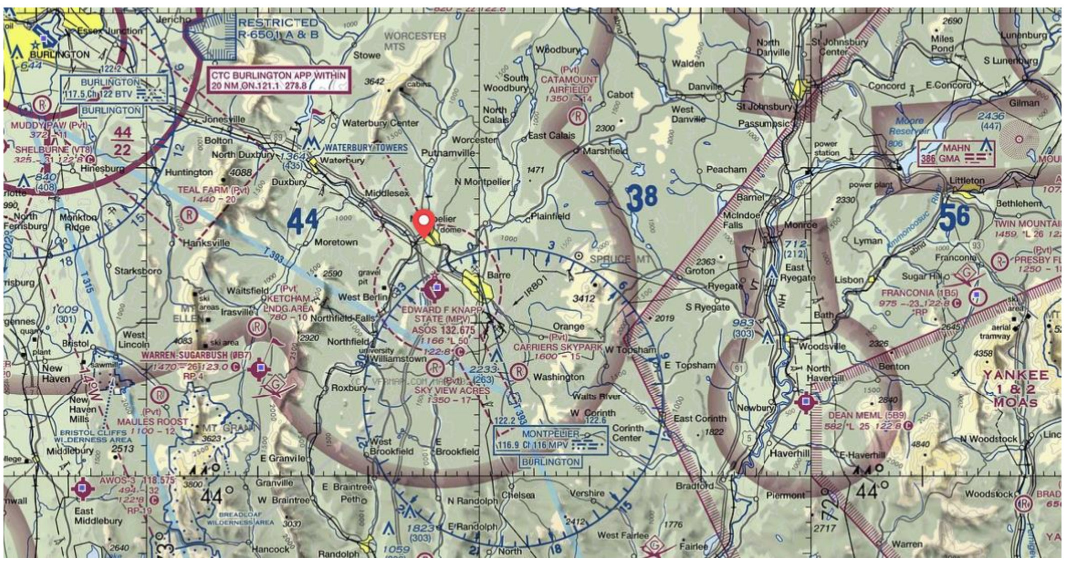



Figure 22. The red point shows the approximate location of the flight in Montpelier, located in Class E airspace.

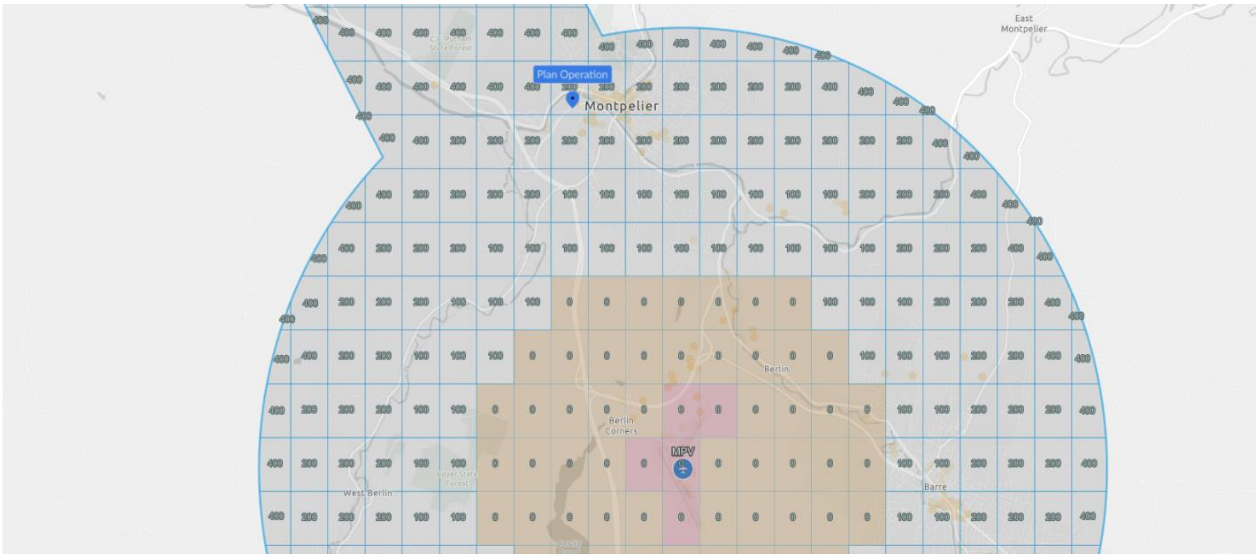



Figure 23. The planned operational area in downtown Montpelier from July 11th is shown at the top of the image and marked by a blue pin. This area is in a 200ft LAANC cell due to its proximity to the MPV airport.

On the morning of July 11, the SAL Director confirmed that Interstate 89 between Burlington and Montpelier was open for travel, with data collection over the flooded state capital being the next priority as tasked through the SEOC and by communications with the UAS Program Manager at VTrans. The UAS Program Manager communicated that the UVM UAS Team was the only group requested for official emergency response UAS operations within the vicinity of Montpelier. Due to the requirement for mapping over a populated area, the flight team operating the senseFly eBee X platforms were requested by the SAL Director and confirmed the tasking at approximately 10:30 EDT. This lightweight fixed-wing UAS platform is efficient at large area data collection and approved for OOP FAA Category 3, which made it ideal for operating in an urban environment such as Montpelier. To comply with OOP FAA Category 3, the platform and sensor configuration had a required maximum weight of 1423 grams that was not exceeded during the flood response flights for this event and others. The flight team took care to select the sensor (senseFly SODA) and battery combination (senseFly Endurance battery) that would ensure OOP-compliance. Additionally, the PIC confirmed that the standard Remote ID capabilities of the platform were enabled and activated.

With the confirmation of tasking, the UVM UAS Team Lead followed up with the SOSC at 11:08 and 11:12 EDT requesting the addition of pilots and UAS platforms to the COA, to account for the OOP-compliant eBee X systems and the flight crew tasked with this operation. The SOSC replied by email with confirmation at 11:13 EDT that the files had been updated with this information, that the existing COA was still valid, and that a new COA would not be issued. The flight team were enroute to the site during this process and was notified by phone call by another UVM lab staff member that the COA had been updated with their information. The COA PDF document that had been issued was shared with the flight team through the lab's internal messaging application to allow for the easiest access by phone or laptop for review prior to beginning operations. To support the generation of flight plans by the flight team from the field, a screenshot of the radius provisioned in the COA was shared to the flight team on Slack, as displayed in **Error! Reference source not found.**. Visual context for the extent of the COA allowed for the flight team to gain a better understanding of the boundaries of this area and to compare the overlay from Google Earth with the basemaps available in the eMotion 3 flight planning software for the AgEagle (senseFly) eBee X platform. The staff member preparing this figure during the event was not aware of a workflow to generate a geospatial file (Keyhole Markup Language (KML), Zipped Keyhole Markup Language (KMZ)) representing the radius to share with the flight team, which could have been imported to the eMotion 3 software for reference during flight planning.

Deploying to the site brought many operational risks due to the state-wide scale of the flooding event, with travel impacts from extensive road closures and limited areas for take-off and landing. These challenges made navigation to the site and flight planning difficult and time consuming. The UVM UAS Team utilized the New England 511 road closure map for updates when navigating to and from Montpelier. Once arriving to the city, the UVM UAS Team had to locate a safe and effective launch and land zone that would not be impacted by flood waters or in the way of other response and rescue teams. The team determined the most suitable location was the top of the parking garage at the National Life Building, which sits on the top of a hill overlooking the downtown area. This location, highlighted with an orange rectangle in **Error! Reference source not found.**, offered a clear line of sight as the UAS flew over downtown Montpelier and a large, flat area needed to facilitate the fixed-wing launch and landing requirements. The team obtained permission from National Life staff to use the space before beginning operations. The flight team provided a Slack message update around 11:30 EDT that they had located a suitable operational location and were in place to prepare for operations.

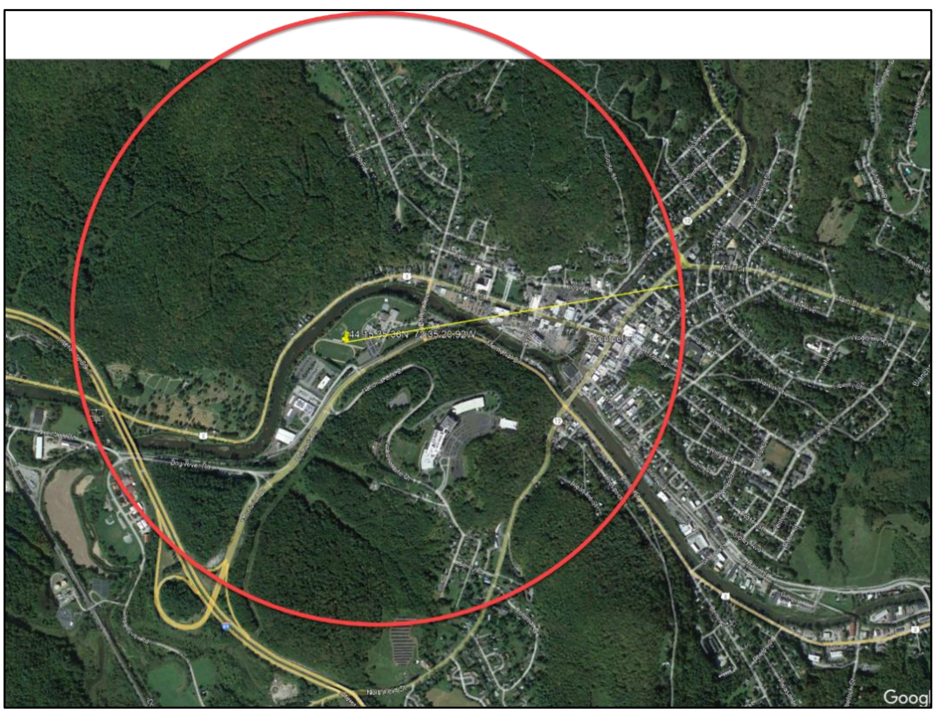


Figure 24. Operational radius (0.75 NM) for flights occuring at or below 400ft AGL as approved in the provided COA.

### *2.21.3 Flood Response Functional Exercise Execution*

The July 11th flood response mission in Montpelier began with pre-flight checks for the site, platform, and team using a custom checklist developed within the software application Fulcrum. This checklist was completed in the field by flight crew personnel on an Apple iPad Mini. It covered the same safety checks and equipment preparation steps as utilized in the March 2023 flood response drill. A Verizon MiFi hotspot was deployed to provide the ground station laptop, crew phones, and tablets with internet connectivity. The PIC, appended to the FAA records for the COA, called the Boston ARTCC (ZBW) to notify of pending UAS operations.

A DJI Mini 3 Pro small multirotor UAS carried out an initial flight at 11:46 EDT. The intent of this initial flight was to gain an aerial perspective of the city, determine the extent of flooding using the live video stream to the controller, and collect oblique photos and videos to provide situational awareness. The launch location on the top level of the National Life parking garage served as a clear and well-defined area for take-off. Manual flight enabled the UAS to be maneuvered to beneficial viewpoints of the city and ensured the platform was not flying over non-participants. From this brief 6-minute flight, the flight crew was able to better understand the site, surrounding flooding conditions, and more accurately design a mapping flight plan to cover impacted portions of the city. Oblique images were captured in JPG + RAW format, while videos were collected in MP4 format with accompanying SRT-format subtitle files providing metadata.

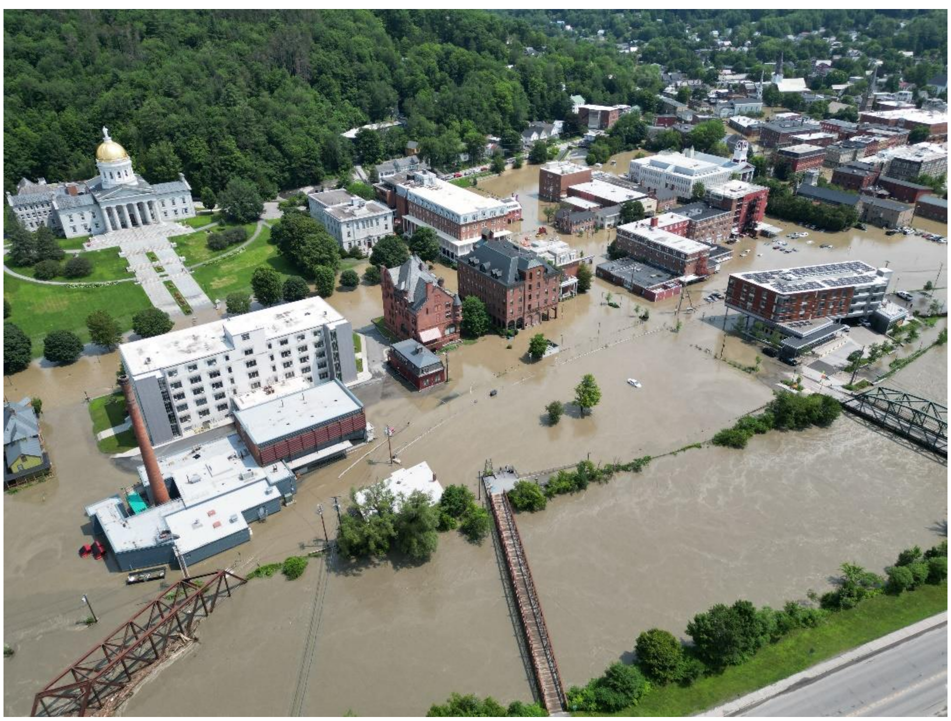


Figure 25. Oblique UAS image of flood conditions captured during initial multirotor flight.

As a result of this information, the fixed-wing mapping flight plan was generated in AgEagle's eMotion 3 flight planning software. The automated mission was designed for the eBee X platform to collect true-color mapping imagery at approximately 375ft AGL, with lateral and longitudinal overlaps of 75% between images. The flight plan, displayed in Figure 26 was designed to capture 1408 images spanning 240 acres, with an estimated time for collection of 77 minutes, likely requiring 2 flights to complete collection. Though this level of image overlap ensures the ability to generate orthoimagery products, it adds inefficiency in data collection – changes to the flight plan to operate at 397ft AGL, with 65% lateral and 70% longitudinal overlap would have reduced the estimated flight time to just 49 minutes, a 25% improvement, and likely the possibility of completing the mapping in a single flight. These adjustments would have resulted in just 887 images being captured, a 37% decrease. In addition to the primary Home/landing location, alternative Home waypoints were included in the flight plan, to allow for the PIC to command the eBee to loiter in these locations should the need arise to give way to manned aviation – a significant challenge with operating fixed-wings systems in highly trafficked airspace is the lack of ability to hover or descend rapidly in place.

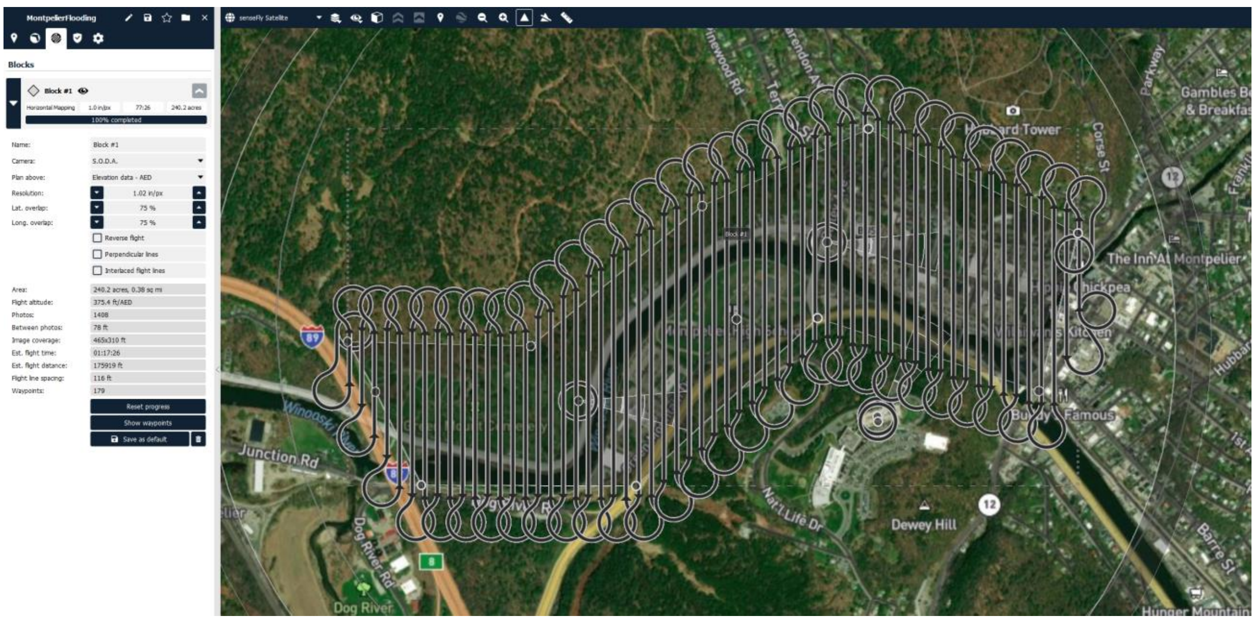



Figure 26. eBee X mapping flight plan for area of interest displayed in eMotion 3 software.

With the flight plan finalized, the flight team was prepared to complete the pre-flight checklists for the eBee X platform, including connecting the communications modem via USB to the ground station computer running eMotion 3 flight software. The flight crew was unable to achieve a connection between the ground station and the eBee X on the newly procured Dell Rugged laptop they were using. Though UVM staff had confirmed that the eMotion 3 software was running as expected during set up of the laptop, the UAS staff did not test the connection between the eBee X's ground modem and the eMotion software. The flight crew placed a call to UVM's UAS Team Lead to discuss troubleshooting steps and contacted the UAS manufacturer's support team for additional troubleshooting. This troubleshooting process took approximately 2 hours to make the connection possible to the UAS system, without success, likely due to limitations of the drivers or USB chipset on the rugged laptop. At 14:15 EDT, the UAS Team Lead located a laptop that would be functional with the system and arranged for delivery of the laptop to the field crew by 14:50 EDT. A secondary flight with the DJI Mini 3 Pro was carried out at 14:18 EDT, lasting just over

4 minutes, to capture additional oblique imagery and video while the new laptop was in route. Upon delivery of the additional laptop, the flight crew utilized a USB stick to save, transfer, and load the flight plans to the new device and were successful at making a connection between eMotion 3 and the eBee X.

The flight crew was able to complete the remaining pre-flight checks and begin the first eBee X flight at 15:25 EDT. Following a hand launch of the UAS by the PIC (Figure 27), the mission began with the flight lines to the farthest west of the mission and the UAS completed flight lines from west to east, working its way back towards the Landing Zone (LZ), the PIC, and the city center. The two supporting Vos assisted the PIC in maintaining VLOS throughout the flight and supported the PIC in providing airspace awareness. Integration of a UAvionix pingUSB Dual-Band ADS-B Traffic Receiver with the eMotion software allowed the PIC to have additional awareness of possible nearby manned aviation, as did monitoring of the CTAF/UNICOM frequency of KMPV airport by airband radio scanner. The maximum distance of the eBee X from the PIC was just under 5400 ft, but due to the profile and flight characteristics of the eBee system, VLOS was achievable.

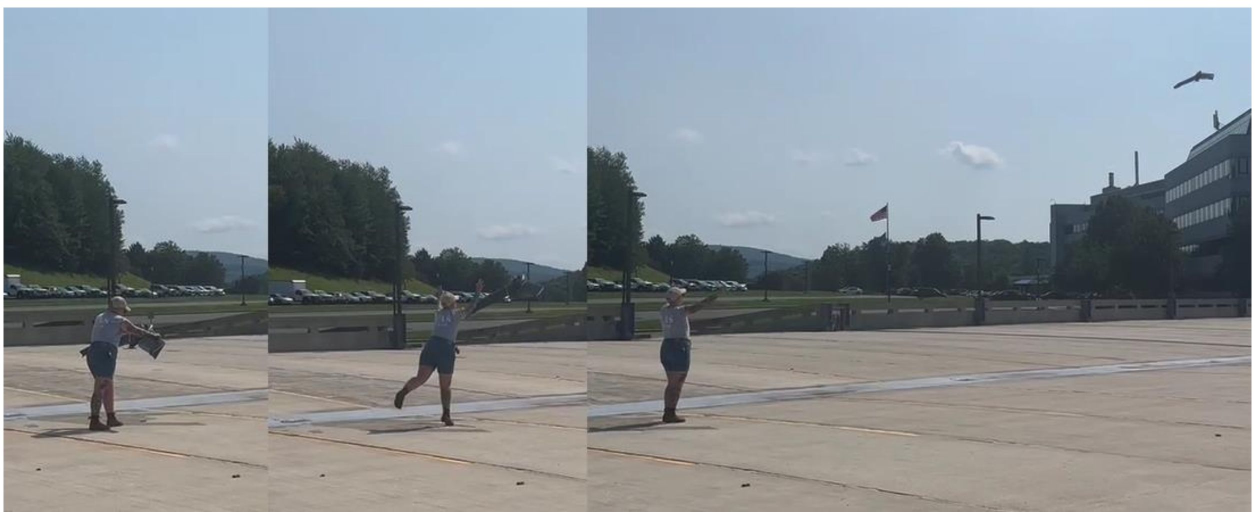


Figure 27. Sequence of eBee X launch by PIC. Note that the PIC had temporarily removed their high-visibility vest identifying them as a UAS PIC for the launch sequence, due to safety concerns with loose fitting fabric and the rear UAS propeller.

Although the top deck of the parking garage was a large, open area well suited for takeoff, the landing procedure at the end of the flight proved more challenging and required adjustments during flight to achieve a successful landing. After commanding the UAS to return home for landing, the PIC aborted the first automated landing approach and adjusted the approach angle. The landing command was issued to the UAS but once again aborted during the final approach as the landing path appeared to be short, with the eBee at approximately 50ft above the take-off location. With this abort, the eBee X climbed back to the altitude of the Home waypoint (246ft above take-off) and the PIC made additional adjustments to the landing location and approach path. The third landing attempt was successful at 16:24 EDT (a 58-minute flight) and the SD card from the SODA sensor was removed and replaced in preparation for a subsequent flight. Due to the need to split up supporting equipment among the multiple UAS teams deployed, the flight crew did not have an adapter to connect a standard SD card to either of the laptops available to them. The rugged field laptop would only accept a microSD card and therefore the decision was made that the team's standard practice of copying images and flight logs from the SODA sensor SD card to the field laptop to ensure data redundancy would not be possible.

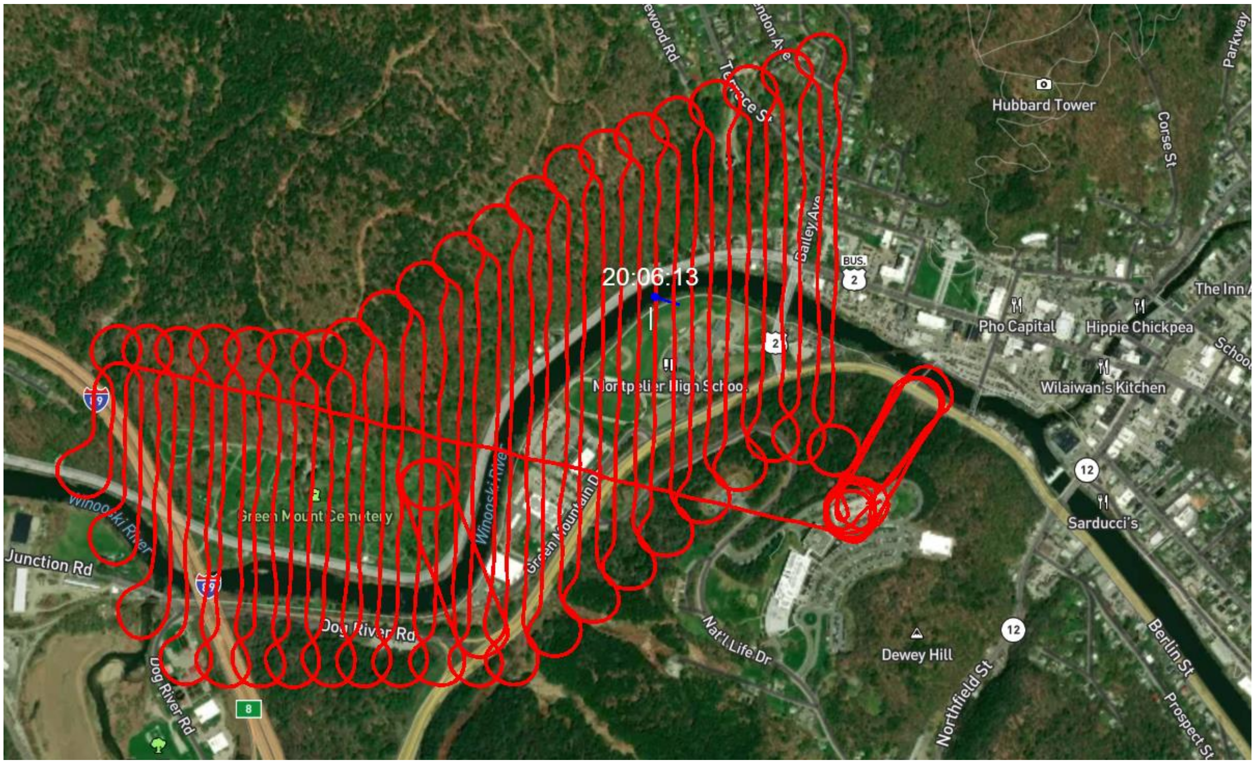



Figure 28. Trajectory of first eBee X flight from 15:25 to 16:24 EDT.

The eBee X was prepared for a second flight, which began 15 minutes after the end of the previous flight at 16:40 EDT. This flight was 25 minutes in length and required just a single landing approach, due to the previous adjustments to the landing approach and location made by the PIC during the previous flight. The flight team extracted the SD card from the sensor, confirmed to SAL staff that their operations were complete on Slack, and called the Boston ARTCC (ZBW) to provide notification that the UAS flight operations were complete. The flight crew packed up equipment and returned to the SAL on UVM campus at 17:55 EDT.

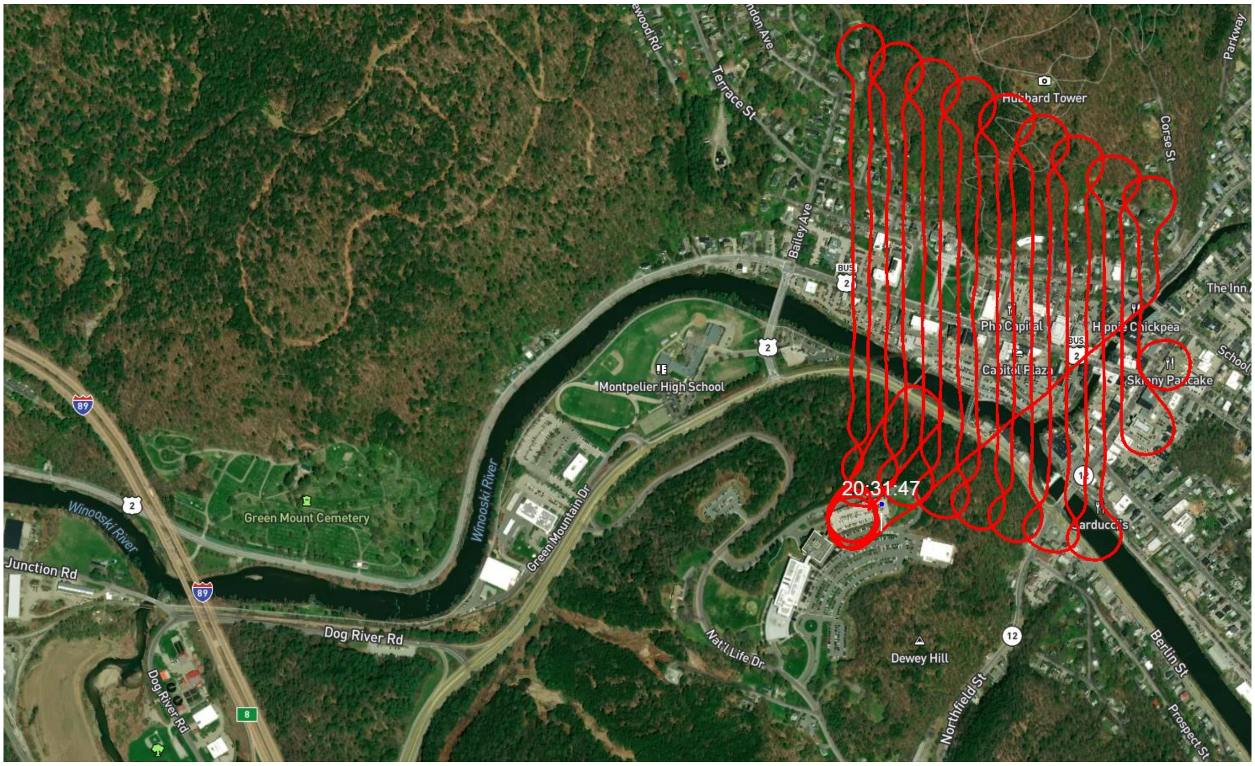



Figure 29. Trajectory of second eBee X flight from 1640 to 1656 EDT.

Following completion of the flight operations, it was critical to share the collected datasets as rapidly as possible. On the return of the flight crew to the SAL, the members copied the contents of the senseFly SODA SD cards and DJI Mini Pro 3 microSD card to a UVM-hosted server system for shared access. The oblique images and videos from the DJI Mini 3 Pro were reviewed and organized for sharing purposes. A selection of JPG-format images and MP4-format video files were zipped to an archive and uploaded to a Google Drive link that the VCGI created to facilitate imagery and video ingestion and dissemination. VCGI offered a standardized pipeline for UVM, VTrans, and Vermont State Police to upload aerial imagery and videos from UAS proved. This was exceptionally valuable to facilitate the most rapid sharing of these basic data products. From the ingest of individual images or zipped archives through Google Drive, the images and videos were added to VCGI's Amazon Web Services storage buckets, before being displayed as selectable points on top of a publicly accessible web mapping application. The points representing the images and videos could be displayed in the approximate position they were recorded due to the file metadata including the GPS coordinates of their capture (EXIF metadata within the JPG images and supporting SRT subtitle files aligned with the MP4 files). A screenshot of the web application is presented in Figure 30.

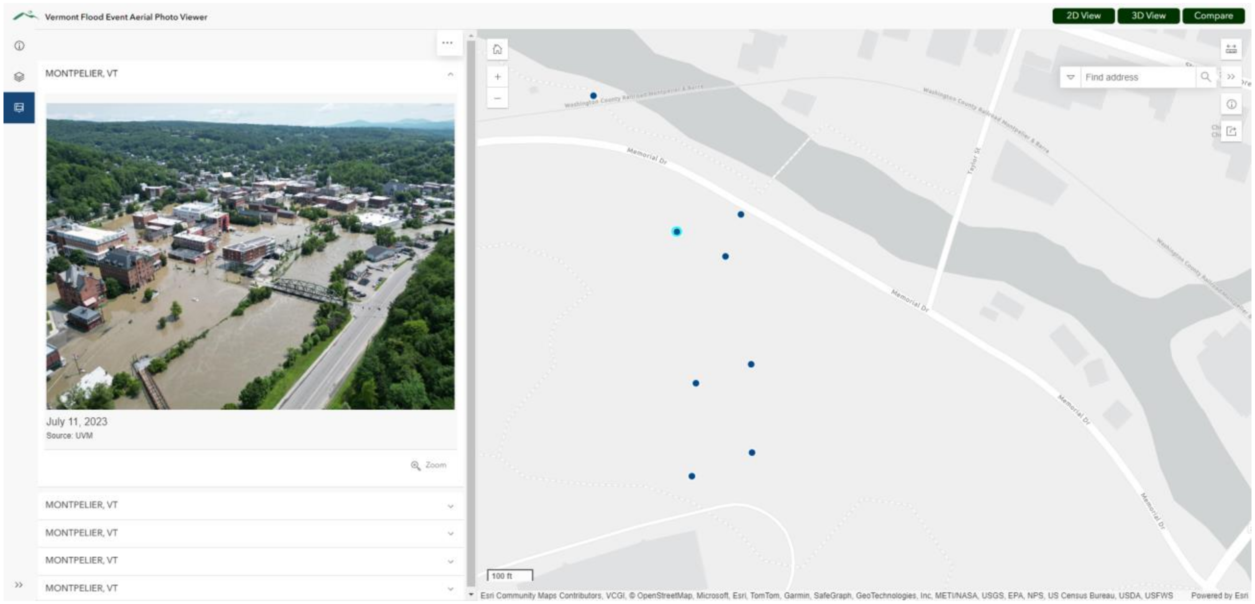


Figure 30. Web mapping application with UAS oblique imagery.

The secondary data dissemination process for this exercise was to generate orthoimagery from the imagery captured during the eBee X flights. A UAS Specialist at UVM utilized Pix4Dreact photogrammetry software to rapidly generate a low-res orthoimagery product by 18:57 EDT, approximately one hour after returning to the lab. Simultaneously, beginning at 16:33 EDT, a UAS Research Engineer accessed and imported the imagery from the eBee X flights to create a new project in Pix4Dmapper photogrammetry software on a high-powered workstation (12 CPU cores, 128GB RAM, discrete GPU). Due to outages with the statewide GPS infrastructure, the VTrans VECTOR VRS network was offline, as was the CORS station typically operating in Montpelier. This precluded the possibility of geotagging the collected imagery with RTK or PPK accuracy. Adjustments were made to processing settings to reduce the time required for all processing steps to complete, with the end goal of having a high-quality orthoimagery product to share. The total processing time required to transform 1408 images into approximately 350 acres of 3.8cm/pixel resolution orthoimagery exceeded 4 hours.

Figure 31. Processed orthomosaic overlaid on satellite basemap imagery.

Upon completion of the processing, the UAS Research Engineer made a copy of the orthoimagery file (GeoTiff format), adjusted the naming of the file to meet the SAL's standard conventions, and notified the SAL Director at 0:11 EDT on July 12 that the imagery product was prepared for sharing to ArcGIS online. The SAL Director imported this orthoimagery product to an ArcGIS Pro project and began the task of publishing the imagery to a tile service at 06:40 EDT on July 12. The publishing of this tile service to ArcGIS Online completed at 09:22 EDT, and the SAL Director adjusting sharing permissions to allow public access, in addition to making a web mapping application by 10:10 EDT. The links to the ArcGIS Online items were shared by email to VCGI for integration to the public web mapping application. The active and idle time required to process and publish the orthoimagery was approximately 6 hours. Visual analysis of the UAS orthoimagery revealed that the imagery was captured shortly after the high-water mark in the city, but the data clearly demonstrated the significant impacts to property.

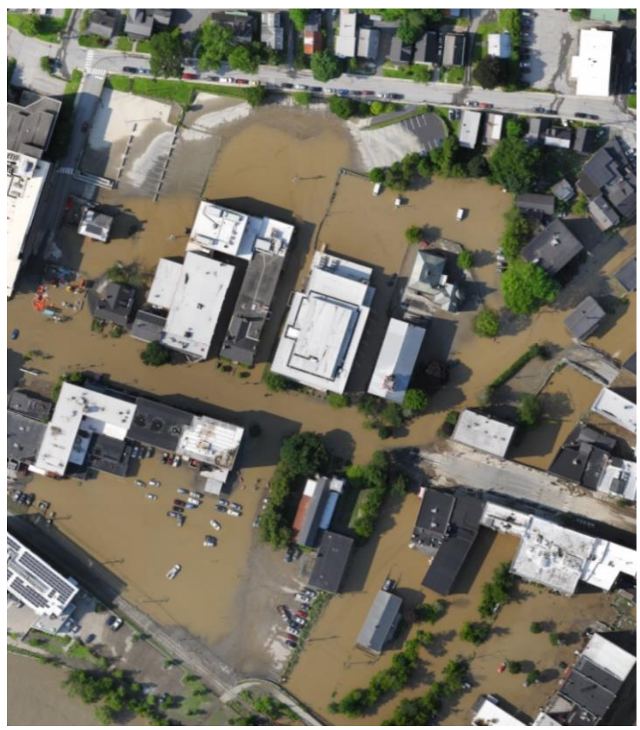


Figure 32. Inset of orthoimagery showing flood waters.

Flight logs from both UAS platforms used during the drill were synced to the DroneLogBook log management platform within 48hrs following flight operations to ensure compliance with UVM's internal policies about flight log retention.

#### *2.21.4 Flood Response Functional Exercise Follow-Up Activities, If Applicable*

The UAS data products generated from this exercise, as well as the other related flight operations carried out by the UVM UAS Team, VTrans, and Vermont State Police, were utilized in multiple fashions by FEMA and to support decision makers in subsequent days and weeks. The FEMA Region 1 Response Division, Planning Branch GIS Team (R1 GIS) were able to ingest the publicly shared ArcGIS Online item within FEMA's GIS database. This data, and the orthoimagery from subsequent missions carried out in the following day and weeks was utilized within hours of being made available on ArcGIS Online during the activation of USAR teams. FEMA's Search And Rescue Common Operating Platform (SARCOP) is an interagency platform with mobile applications, web-based applications, and advanced geospatial analytics in a single place to map out operations and provide search coverage analysis. UVM work directly with the SARCOP GIS team to ensure that imagery could be loaded into the dashboard as soon as possible – this connection was facilitated through contacts at R1 GIS.

FEMA HQ activated GDA capabilities, with the goal of providing unofficial first look damage assessments within 72 hours of impact for all decision-makers including external partners. R1 GIS consolidated and disseminated the UVM-provided UAS datasets so that assessments could be conducted by the HQ team. An overview of the GDA process, utilizing UVM's UAS orthoimagery, was presented in FEMA Coordination Call at 15:00 EDT on July 14, as shown in Figure 33. It was noted during this meeting that a clear sign of damaged property to the analysts carrying out GDA was if a property was inundated with floodwater in the captured UAS orthoimagery. Therefore, it was stressed that urgency and timing of data collection was important to allow for the most rapid GDA possible. UAS orthoimagery captured after flood waters receded adds significant difficulty to the analysis process, whereby analysts now must rely on more detailed image interpretation to look for impacts of flood debris or other context to make the determination.

UVM representatives were informed by R1 GIS staff that the UAS data shared may have sped up the process to receive a federal disaster declaration by several weeks. On July 13, 2023, just one day after the UAS orthoimagery from this operation was made available, the State of Vermont requested an expedited major disaster declaration, which utilized sets of UAS imagery and data products as supporting material to illustrate the extent and impact of the flood events. This, in addition to the results from the GDA, contributed to a federal major disaster declaration being rapidly declared on July 14, 2023.

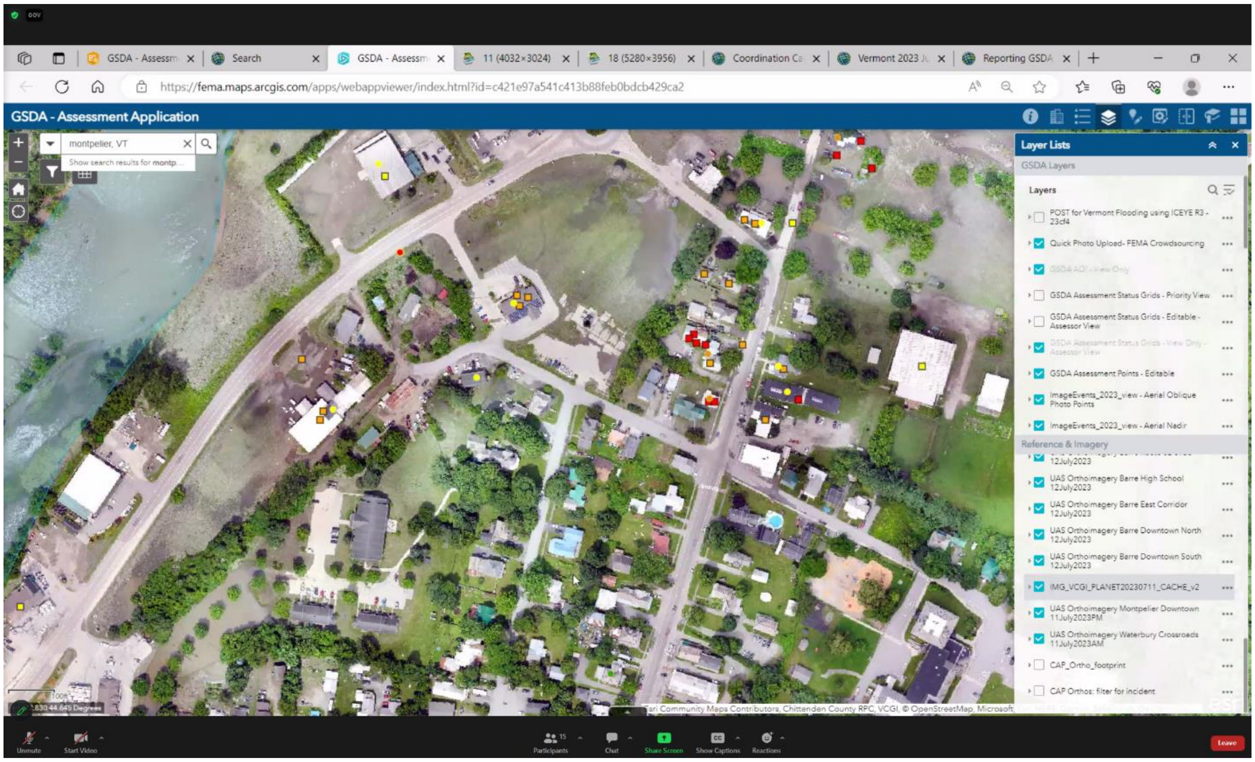



Figure 33. GDA in progress utilizing UVM-provided orthoimagery.

Data management, especially as follow-up activities and UAS mission tasking continued throughout the state as a high operational face, became increasingly important by July 12. The SAL Director developed an excel spreadsheet to ensure that the organization had a single document to list basic flight details and data product locations. The operations in this case study were among the first three flight operations completed in response to the flood events. A UAS Research Engineer adopted the role of 'data manager' through the rest of the response and added additional functionality, including automations, to the tracking spreadsheet to allow for tracking of platforms, pilots, geospatial corrections, data paths, flight log syncing, and the status of data processing, management, and public sharing. Between July 10 – August 23, 2023, this spreadsheet grew to contain 102 individual line items representing mapping missions. The capture of oblique images and videos were not included within this living database. The SAL maintained existing standard practices for file management, organization, naming, and metadata management for UAS data (flight products and generated data) which was valuable to ensure that even in stressful situations, flight crews, data managers, and supervisors could reliably know where to locate required datasets and ensure that completed orthoimagery products were shared with VCGI for greater public dissemination. After carrying out flight operations between July 10-12, the Research Engineer served full-time as the 'data manager' until August 23 and was the primary individual carrying out data processing and sharing workflows for each UAS mission set completed. In total, UVM collected and generated more than 2.8TB of UAS data during the complete period of this response. This functional exercise discussed resulted in 12.7GB of imagery, video, and logs from the flight operations and 13.3GB of locally stored processed products.

UVM consulted with Esri's Disaster Response Program beginning on July 15, 2023, to assist in further optimizing the workflow for orthoimagery generation and rapid sharing to ArcGIS Online. Per these discussions, the UVM UAS Team pivoted to use of a cloud-based processing solution (Esri SiteScan) for orthoimagery processing, rather than localized photogrammetry processing software within the SAL. The benefits of this adjustment were numerous:

- Ability to process dozens of missions simultaneously, without bottlenecks related to available local computer resources.
- Direct sharing of orthoimagery as tile service to ArcGIS Online via cloud-to-cloud transfer simplifies and increases efficiency to alternative multistage local process and publish workflow as utilized in this functional exercise.
- Reduced local data storage needs, as only desired final products can be downloaded for local offline analysis.
- Possibility to allow for flight teams, should they have sufficient broadband access (i.e. Starlink), to upload, process, and/or publish datasets while in the field
- Simple workflow for including processing of 3D mesh outputs and sharing those directly to ArcGIS Online in a compatible format (Figure 34). Vermont's governor expressed significant interest in the capability to generate 3D mesh to allow for intuitive visualization by officials or members of the public who are not emergency responders.

Cloud processing with Esri SiteScan did introduce several new challenges:

- Limitations to maximum number of input images that can be processed for a single dataset
- Requires reliable broadband internet connection and sufficient upload speeds to push input image sets to the cloud.
- Provides less ability to adjust settings to improve processing results, especially in areas of dense forest and over large areas of standing or moving water. Several projects produced poor results in SiteScan and were then processed using Pix4Dmapper in an attempt to improve the results.

Figure 34. 3D Mesh generated by Esri SiteScan.

As previously discussed, following this functional flood response exercise, UVM continued to carry out UAS operations in support of response and recovery efforts in Vermont at a significant operational pace over the next six weeks. Many of the lessons learned during this real-world event presented in this exercise were addressed within hours or days to improve the operational efficiency and safety of UAS operations, in addition to the enhancing the ability to rapidly provide UAS data products to decision makers.

### *2.21.5 Lessons Learned from the Flood Response Functional Exercise, Including Responses to Research Questions*

#### 2.21.5.1 Flood Response Functional Exercise Key findings:

1. Effective internal communication within an organization tasked with UAS operations was critical. UVM communicated internally through an internal messaging application, mobile calls, text messages, Microsoft SharePoint files, and other methods to ensure that everyone was aware of their tasks and any potential concerns as they arose.
2. Daily team briefings in the morning and evening, either in-person or online, allowed for effective communication of priorities, assignments, and required adjustments needed to sustain safe and effective operations.
3. Having pre-established relationships with other UAS operators and geospatial organizations/agencies within a state and region is critical to ensure that teams with the required types of UAS resources and capabilities can be deployed. UVM was the only organization within the state operating any OOP-compliant UAS.
4. Relationships with UAS specialists at VTrans and Vermont State Police allowed those teams to pass appropriate tasking to UVM, as they were familiar with UVM’s capabilities.
5. Relationships with VCGI and FEMA R1 GIS staff allowed for the rapid development of data sharing workflows.

6. Timely email and telephone communication with the FAA SOSC to receive COAs through the SGI process were essential to allow for UAS response efforts, especially when capturing orthoimagery of high-water levels was critical for GDA.
7. COAs issued through SGI are not reissued when amendments are made to UAS systems or authorized flight crew (PICs), though they are recorded internally by the SOSC.
8. The SOSC requests that UVM, as a university, provide a letter of support/tasking from a recognized state agency to be validated as a 'governmental' organization supporting response efforts. The SOSC was not aware of UVM's status as a core-member of ASSURE, with specific research objectives to investigate and carry out disaster response with UAS.
9. A 'response coordinator' for organizations with the capacity to deploy multiple UAS teams was critical to allow flight teams to focus on maintaining readiness, executing operations, and managing data. The SAL Director served in this role and attended coordination calls with external local, state, and federal organizations, in addition to conducting outreach to impacted communities with offers of UAS support.
10. The adoption of standard operating procedures during routine, non-emergency UAS operations allowed UVM UAS teams to jump into action during an emergency event without wasting essential time. Familiarity with custom checklists developed for each UAS platform, sensor, and mission type possible saved crucial time by providing specific guidance on the equipment needed to be prepared for an operation (batteries, supporting equipment, spare parts).
11. All equipment, including both sUAS and supporting components, should be thoroughly tested for functionality prior to deployment to avoid the need for troubleshooting in active emergency response situations.
12. The ability to dispatch or obtain back up sUAS, sUAS accessories, and/or supporting equipment (i.e. ground station laptop) can make the difference between actionable data being captured or not.
13. It is beneficial to conduct a preliminary manual flight with a small multirotor UAS platform before completing a large, automated mapping mission. This initial flight can be helpful in several ways:
    - Aids in determining the extent of flood impacted areas, allowing for adjustment of mapping flight plan to ensure no critical areas are missed. This can be accomplished in real-time using the live video feedback.
    - Facilitates capture of oblique images and video that can provide valuable contextual information to the extent of impacts and can be published rapidly, with the possibility of sharing images directly from the field.
    - Supports assessment of the area for potential unexpected obstacles prior to mapping mission.
14. OOP-compliant UAS platforms, particularly fixed-wings, are extremely efficient and effective systems for flood mapping. Floods can have widespread impacts across urban areas, where the presence of dense populations can increase risks in UAS operations. Mapping hundreds of acres over a city center would prove otherwise difficult, if not impossible, in compliance with Part 107 regulations.
15. It may be possible to refine mapping mission plan parameters (lateral image overlap, longitudinal image overlap, altitude, flight speed) depending on platform and sensor to increase operational efficiency.

16. Ensuring that fixed-wing sUAS are able to yield ROW within airspace is challenging, due to their lack of ability to hover in place. The creation of multiple, low altitude (<200ft AGL) waypoints spread throughout the mapping area provided the RPIC with immediate and actionable resolutions if/when deconfliction was needed due to manned aviation or other unexpected sUAS. The RPIC was prepared to command the sUAS to immediately transit and loiter at the nearest of these waypoints until the mission could be safely resumed.
    - Large scale UAS deployments, particularly spanning over dozens or hundreds of missions; over days, weeks, or months; and/or with the deployment of multiple UAS teams requires significant effort to ensure the captured data is managed and shared as rapidly as possible.
17. A 'data manager' role was invaluable in ensuring that the UAS flight teams could focus on continuing their operational tempo of data collection
18. A custom-designed shared spreadsheet was refined through the response effort to allow for tracking of tasking updates, schedule of data capture, operational details (if any), data processing steps, and confirmation of data publication and sharing.
    - True-color UAS orthoimagery is a reliable data product to support FEMA's GDA. Imagery that is captured at or near peak flood conditions allows the most rapid GDA process.
    - True-color UAS orthoimagery is a reliable data product to support Urban Search & Rescue efforts through ingestion to FEMA's SARCOP platform.
    - Publishing UAS orthoimagery as tile services to Esri's ArcGIS Online platform, with public sharing enabled, is an ideal workflow for rapid sharing and ingestion by the FEMA region geospatial coordinators, who serve as the 'hub' of a hub-and-spoke model of geospatial data dissemination.
    - Processing orthoimagery in cloud services may provide benefits to efficiency of data generation and sharing.
    - Having workflows in place to facilitate sharing of oblique images and videos to the public and decision makers is key to transforming those into actionable data.

**2.21.5.2 Flood Response Functional Exercise Recommendations:**

- Continue to work within states and regions to ensure relationships are established between organizations operating UAS, as well as connecting those groups with geospatial organizations/agencies within a state and region is critical to ensure that teams with the required types of UAS resources and capabilities can be deployed. Specific understanding of the capabilities and capacity of each organization that can provide UAS support is critical to assign appropriate tasking. State-wide or FEMA region-level UAS responder working groups may be advised.
- Ensure that UAS operators understand and can carry out requests for waivers/COAs through the SGI process. Development of training courses, materials, or best practices for an SGI request would be practical.
- Consider integration of geospatial files to support SGI request workflow.
    - In addition to text-based location delineation, SOSC could intake KML/KMZ files to define operational boundary as these files are common for UAS operators to use to define their flight areas.
    - SOSC could issue KML/KMZ files with COA to provide boundaries of area of approval, especially if location is submitted in SGI request form by text. Allowing UAS

operators to integrate this into their flight planning software to ensure compliance with COA conditions.

- Consider development of a FAA database to identify trusted emergency response UAS operators and organizations would allow for 'non-traditional' public agencies, such as universities, to more rapidly proceed through SGI request workflow without the requirement for a letter of support from a state agency.
- Establish a 'response coordinator' within an organization that has the capacity to deploy multiple UAS teams. This can allow flight teams to focus on maintaining readiness, executing operations, and managing data.
- The development of common UAS tasking solutions, with particular attention to geospatial integration, would provide significant benefits in tasking UAS flight teams that may be able to provide unique or specialized mission profiles.
- Ensure usage and adoption of standard operating procedures during routine, non-emergency situations.
- UAS operators and flight crew should complete regular testing of the integration of supporting UAS equipment and software for functionality prior to deployment to avoid the need for troubleshooting in active emergency response situations.
- Make contingency plans to dispatch or obtain back up sUAS, sUAS accessories, and/or supporting equipment. This could be the difference between valuable data being collected and not.
- Conduct a preliminary manual flight with a small multirotor UAS platform before completing a large, automated mapping mission to provide RPIC with situational awareness and adjustment of automated mapping flight plans to account for situation on the ground.
- Encourage the deployment of OOP-compliant UAS platforms, particularly fixed-wings, for large -scale flood extent mapping over urban centers. Increase UAS operator knowledge about approved OOP systems and their requirements for compliance.
- Investigate potential standards for imagery overlap and altitude recommendations to facilitate the most efficient mapping flight operations possible, while balancing the need for quality data to generate orthoimagery.
- For fixed-wing sUAS, establish multiple, low altitude (<200ft AGL) waypoints spread throughout the mapping area to provide the RPIC with immediate and actionable resolutions if/when deconfliction was needed due to manned aviation or other unexpected sUAS.
- Ensure that RPIC considers emergency actions required in-flight to yield ROW to manned aviation. Establish these protocols within pre-flight checklists.
- Plan for and enact solutions to manage data during large scale UAS deployments, particularly spanning over dozens or hundreds of missions; over days, weeks, or months; and/or with the deployment of multiple UAS teams.
    - Establish a 'data manager' role, to ensure that UAS flight teams can focus on continuing their operational tempo of data collection.
    - Develop a solution to manage data tasking, processing, and sharing. This could be a custom or standardized spreadsheet or utilize a dedicated software solution.
- Direct primary flood response tasking towards collection of true-color UAS orthoimagery, especially at or near high-water levels. This supports both FEMA's GDA and search & rescue efforts via FEMA's SARCOP platform.

- Establish scalable workflows for dissemination of UAS orthoimagery as tile services to Esri's ArcGIS Online platform, allowing for direct ingestion by FEMA Geospatial Coordinators.
- Consider processing orthoimagery in cloud services to provide benefits in the efficiency of data generation and sharing.
- Establish scalable workflow to facilitate sharing of oblique images and videos to the public and decision makers.

#### 2.21.5.3 Flood Response Functional Exercise Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. A multirotor sUAS enhanced situational awareness by providing the team with real-time observation, photos, and videos of the flooding conditions in Montpelier from an aerial perspective. UAS orthoimagery was utilized to support FEMA GDA, search & rescue operations through integration to FEMA's SARCOP platform and used to support disaster declaration requests from states to the federal government.
2. The primary coordination and cooperation between agencies involved in this UAS response was conducted before flights took place, as opposed to real-time communication during operations. A UAS Program Manager working directly for the state agency of transportation understood the capabilities of UVM's UAS team and directed tasking for OOP mission profile to UVM.
   - UVM was notified that they were the only organization tasked with UAS operations over this location and that no other UAS response would be occurring simultaneously.
   - Receiving SGI approval required a combination of effort across multiple organizations. The SGI request for this exercise was submitted by the UVM UAS Team and included a statement from VTrans stating that their organization required UAS assistance for the flood response.
   - Consistent and rapid communication between UVM and SOSC allowed for operations to occur near peak flood conditions.
   - Notification to Boston ARTCC (ZBW) of impending and completed flight operations provided FAA with oversight and capacity to notify manned aviation within the response area of the UAS operations.
   - Established relationships between UAS-enabled organizations (UVM) and geospatial agencies (VCGI, FEMA R1 GIS) allowed for development of rapid sharing of the resulting data products.
3. A risk in this scenario was operating within Class E airspace and in vicinity to manned aircraft. This could be mitigated by:
   - Deploying VO(s) to support RPIC in monitoring airspace
   - Utilizing ADS-B receivers for situational awareness
   - Monitoring airband radio scanner to be aware of communications on CTAF/UNICOM in vicinity
   - Identifying and being prepared to execute emergency procedures to yield ROW during the flight. During this exercise, the RPIC established multiple loiter waypoints at a lower altitude than the flight path.

Operation of UAS over urban/populated areas increases risk to the public. These risks can be mitigated through the deployment of OOP-compliant UAS, completion of applicable pre-flight checklists, and establishment of routine maintenance schedules as recommended by the manufacturer to ensure reliable operations.

During extended emergency operations, RPICs and flight crews may be subject to a variety of stress factors including fatigue and external stressors. Utilization of Crew Resource Management techniques, including the application of checklists like PAVE and IMSAFE, in addition to the development of potential standards related to rest and operational tempo as they relate to sustaining safe operations, could be valuable.

4. N/A
5. A multirotor with a true-color camera and video livestream to the UAS controller would be a suitable platform to provide real-time situational awareness and collecting obliques images and videos.

   A fixed-wing or VTOL UAS with true-color camera designed for collection of mapping orthoimagery is a suitable platform to carry out large-scale (hundreds of acres) of mapping due to their long battery life and efficiency. Over a populated area, this platform should be OOP-compliant.

6. Situational awareness/oblique imagery and video
   - Small system, portable, simple and rapid deployment capabilities
   - Gimbaled EO sensor providing real-time video feed and capacity to capture JPG images and MP4 video
   - Flight time of at least 10 minutes
   - Remote ID

   Mapping flood extent over urban area

   - OOP compliance
   - EO sensor capable of collecting JPG imagery of at least 10cm resolution for photogrammetry processing
   - Flight time exceeding 30 minutes
   - Remote ID
7. FEMA cannot directly task UAS data products, so developing solutions to distribute UAS data in a publicly available manner allows for the ingestion by FEMA Geospatial Coordination teams.
   - This may occur at a state partner level, such as VCGI publishing the orthoimagery products developed by UVM.
   - There may be value in the development of standard practices for state, local, or regional organizations to share UAS orthoimagery with their regional FEMA GIS office.
   - FEMA R1 GIS is comfortable with the ingestion of imagery products shared through Esri's ArcGIS Online solution.
   - FEMA could develop 'best practices' manual for public partners to efficiently share UAS data with regional geospatial office, ensuring consistency within each region and across the nation.

State-level UAS and/or geospatial organizations should establish relationships with regional FEMA GIS office to ensure rapid coordination can occur during an emergency event.

UAS operators should be familiar with the data types and potential uses of each by FEMA

- True-color orthoimagery, ideally captured during high-water conditions: GDA, SARCOP integration, supporting disaster declaration requests
- Oblique imagery/video: GDA, supporting disaster declaration requests

8. A stipulation of the COA issued through the SGI process was that any Lost Link departure of the operation area must be reported to Boston ARTCC (ZBW). Ensuring that C2 links are secure and reliable remains a priority, especially during large-area mapping missions that may span hundreds or thousands of acres.
9. N/A
10. Ensure that UAS operators understand and can carry out requests for waivers/COAs through the SGI process. Development of training courses, materials, or best practices for an SGI request would be practical.

    Develop common UAS tasking solutions, with particular attention to geospatial integration, would provide significant benefits in tasking UAS flight teams that may be able to provide unique or specialized mission profiles.

    Investigate potential standards and guidelines for imagery overlap and altitude recommendations to facilitate the most efficient mapping flight operations possible, while balancing the need for quality data to generate orthoimagery.

    Develop best practices for data management during large scale UAS deployments, particularly spanning over dozens or hundreds of missions; over days, weeks, or months; and/or with the deployment of multiple UAS teams.

    Establish scalable workflows for dissemination of UAS orthoimagery as tile services to Esri's ArcGIS Online platform, allowing for direct ingestion by FEMA Geospatial Coordinators.

    Establish scalable workflow to facilitate sharing of oblique images and videos to the public and decision makers.

    Develop national, regional, or local database of trusted organizations/operators that can provide specific UAS mission profiles.

    As Remote ID continues to evolve and become more widely used, and more pilots are equipped with Remote ID receptors, this will also improve airspace deconfliction during disaster response.

    Provide guidance and training on the deployment of OOP-compliant sUAS and the limitations associated with operating non-compliant systems over urban areas.

11. In a flood response scenario such as this one, UAS can provide:
    - Low altitude support of SAR operations and ability to swap sensor type (RGB, thermal)
    - Rapid response and mobility
    - Ability to livestream high resolution video
    - Capacity to map dozens or hundreds of acres within minutes or hours after tasking

- The ability to operate in short windows of time between rain or other weather events that may prevent manned aviation from taking off
- Ability to operate below clouds, which could limit manned aviation imagery/data collection
- Lower-cost option compared to manned aviation
- Access to rural communities that may be located further from certain types of manned aviation and other response resources

#### 2.21.5.4 Flood Response Functional Exercise Lessons Learned Summary:

UAS played a crucial role in the response to the severe flooding events that took place across Vermont in July 2023, as illustrated in this functional exercise. These systems enabled rapid deployment and data collection in areas that were otherwise inaccessible, proving invaluable in an urban environment where timely information was critical. The ability to operate an OOP-compliant UAS platform allowed for data collection over a highly impacted city center. A small multirotor UAS was well suited for rapidly providing a UAS flight crew with real-time situational awareness and capturing oblique images and video in areas of limited space before carrying out a mapping mission. The data collected from UAS operations offered a comprehensive view of the flooding's peak extent, supported detailed damage assessments, and served as essential documentation for future flood resiliency research and planning efforts.

The successful coordination between various response organizations during this event facilitated efficient data collection in high-priority areas. Reliable communication between UVM and the FAA SOSC through the SGI request procedure allowed for a COA to be issued in a timely manner so that UVM could attempt to capture data as near to peak flood conditions as possible.

Coordination with state-level geospatial personnel and relationships with regional FEMA GIS personnel allowed for the rapid development of data sharing protocols, to put the generated orthoimagery in the hands of FEMA GDA analysts and to support on-going SAR operations, through integration with FEMA's SARCOP platform. Sharing UAS orthoimagery within hours of collection to FEMA and the SEOC provided tremendous value to decision makers and expedited the federal disaster declaration by several weeks.

Beyond focusing on the UAS flight crews carrying out these types of flood response activities, it is critical to focus efforts on understanding the roles of supporting personnel with focuses on mission tasking and data management/processing. This is particularly critical for response cases that involve significant numbers of flights over days or weeks, and/or the deployment of multiple UAS flight crews and platforms with unique capabilities.

## 2.22 9/8/2023, Functional Exercise, Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS), Fairbanks, AK to Nenana, AK, Conducted by UAF

Amid a pandemic crisis, a remote rural community finds itself critically undersupplied, with no viable road access available. The only lifeline is through airborne transport, but even this option is hampered by adverse IFR conditions, rendering crewed flight systems inoperable. Additionally, the local river, typically a vital transportation route, is rendered unsafe due to the presence of thin ice and hazardous ice blocks.

#### 2.22.1 Objectives of the Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Functional Exercise

The main objective of this functional exercise was to deliver critical medical and community supplies between two locations, when the second site is cut off from the road network during a pandemic event and the river is unsafe to use due to thin ice and ice blocks. Also, they do not want people moving between communities to minimize contact and any potential spread.

A lUAS was flown from Fairbanks to Nenana and back. First mission was to fly from main hub to rural community. Return flight was focused on returning to main hub to prepare to move towards future cargo delivery between two sites. Flights began at the major hub international airport, land at smaller rural community airport, and aircraft returns to land at the major hub Class D airspace international airport.

#### 2.22.2 Planning for and Logistics of the Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Functional Exercise

Prior to the operations from September 6 – 8, the UAF-ACUASI team worked closely with the FAA to ensure that the ground control station for the Nenana based crew met the requirements to ensure safe flight operations out of Nenana.

Discussions focused on ensuring that the trailer used by the ground crew was situated in the correct location relative to the runway for operations at Nenana Regional Airport, ENN. The UAF-ACUASI team had received the COA to ensure safe flight operations and worked between July 24 and August 21 to ensure that the ground crew equipment was in the correct location and that all paperwork was filed with the FAA to show that the UAF-ACUASI team had all equipment correctly placed.

Permission was received on August 21 to state that the Fairbanks to Nenana and back operations could be performed. The UAF team and those supporting the operations then worked to define the timing of the exercise flights, given other operational missions for the ACUASI team and availability of the team to collect the data for A52 during the flights.

The week of September 6 – 8, 2023 was selected as the appropriate time to carry out the lUAS functional exercise under A52. UAF-ACUASI had previously worked with Fairbanks International Airport on past flight operations and had developed the logistical process for the flight operations from Fairbanks for the lUAS exercise. UAF-ACUASI had also worked to set up their ground crew and equipment to ensure that the team adhered to the COA and permissions to complete the FAI to ENN and back missions.

#### 2.22.3 Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Functional Exercise Execution

*[More details included in Medical Delivery Between Major Hub and Rural Community (IUAS) Functional Exercise Functional Exercise – Notes and Lessons Learned]*

The flights occurred from September 5 to 8, 2023 and centered on finding weather windows for safe operations. The first flight was a one-way operation from FAI to ENN, and the second flight (on the next day) was a two-way operation from FAI to ENN, landing, and then a return to FAI.

*Day 1 – September 5*

Weather conditions prevented safe flight operations. Meteorological Aerodrome Reports (METARs) were used to monitor the weather conditions and assess the forecast for the day. All flight operations for the day were cancelled and the flight crews (one for FAI; one for ENN) prepared for flight operations the following day.

*Day 2 – September 6*

The two flight crews and the support teams met to determine if safe flight operations could occur during the day. In the morning, cloud cover in Nenana (ENN) showed two layers at 1100ft and 1700ft when in Fairbanks (FAI) showed scattered clouds at 1300ft and 2900ft with an overcast deck at 4200ft.

08:00 Local Time (LT, 16:00 UTC) – Flight brief on who would be part of the flight crew for each location and role of the chase plane to ensure VLOS throughout. Based on weather conditions, crews made the decision to re-check at 10:00 LT (18:00 UTC).

Note that for operations, if a decision made to fly based on weather conditions was made, then it would be +1 hour until takeoff would be possible.

Re-check weather at 10:00 LT (18:00 UTC). Reviewed current conditions and forecast. Possible flight times could be 12:00 LT (20:00 UTC), and 14:00 LT (22:00 UTC). However, weather forecast showed light rain and cloud ceilings that would prevent safe operations.

At 10:58 LT (18:58 UTC), flight operations cancelled for the day and decision made to prepare teams for flight operations on the next day.

*Day 3 – September 7*

Operations brief at 08:00 LT (16:00 UTC): Flight will be Fairbanks to Nenana [PAFA/FAI to ENN]. Chase plane provided by local helicopter with a VO on board. VO = Nick. Crew at ENN: Jason (PIC) and Matt (Secondary Pilot). Bremner as VO/crew. Crew at FAI: Andrew (PIC) and John (Secondary Pilot). Brian and Zack as VO and crew. Chase helicopter will depart from Chena Marina, as we launch SeaHunter. VO's will be around FAI, one at take-off and one at Hangar. Planned launch at 10:00 LT (18:00 UTC).

10:00 LT (18:00 UTC) Weather review: PAFA/FAI METAR. Decision was made to hold and review at 12:00 LT (20:00 UTC). Flight operations lead for the day (Robinson) communicates with all in flight crews and support via text. This was determined as communication tool to use to inform all.

13:00 LT (21:00 UTC) Weather review: FAI – Broken at 1500 ft; Overcast at 3200 ft. ENN – Broken at 3600 ft. Lead for operations and Pilots made the decision to spin up the operations team to fly (text sent to all in the operations).

Flight deployment from hangar: Planned takeoff at 15:00 LT (23:00 UTC). VO to report to the hangar at 14:00 LT (22:00 UTC). Text communications used to inform all on the operations. Sent by the lead for the operations, who lead the briefing. Flight will be one-way so that the crew in ENN will dissemble the lUAS and drive back to Fairbanks after flight. FAI team leaves hangar onto the site. ENN team leaves at 13:20 LT (21:20 UTC) from Hanger. Team (PIC – Jason, Secondary Pilot – Matt, VO/Crew – Bremner). 2 Pilots with VO/Crew. Use truck to bring aircraft back to Hanger. Will be on radio at GCS, call to the FAI crew once they arrive at ENN.

*The following details are from recorded notes on execution from team member at the FAI crew site during the exercise.*

Flight preparation: Crew does walk around checklist by the book for the aircraft and informs PIC. Audio check. GCS to ground VOs and chase VO. Heli takes off 10 minutes prior to take-off. Radio check to Hanger VO, 10 mins before take-off. After VO/Crew Walk around, GCS team get ready.

Pre-Flight checklist: PIC and Secondary pilot go through Section 1.3 of SeaHunter handbook. Note that Secondary Pilot reads it, and PIC confirms. VO/Crew does checks on the aircraft at the same time to follow checklist. Turned on VHF radio to get up to date cloud information. Another weather checks closer in time to flights. Stopped to confirm the weather data and wrote details onto white board for future reference.

Pre-Flight Checklist continued, 15:10 LT (23:10 UTC): Engine Run checklist. Section 1.4 of the SeaHunter handbook. PIC reads the book and SIC checks. SIC runs each engine. Left 1st and then right. PIC writes into the checklist sheet. PIC performs radio communications to the tower. Cleared for taxi at 15:20 LT (23:20 UTC). SIC performs communications check to VO at Hanger on local radio.

Taxi to take-off: Manually by SIC. Travel from GCS site to the launch location. PIC in communications with the tower. Autopilot for launch, 15:29 LT (23:29 UTC). PIC communications to the tower to confirm departure. Take-off completed. PIC goes through checklist from book for post take-off process.

Flight in process: FAI GCS team moves to the hand-off checklist for the SeaHunter (Section 1.18 of handbook). Phone call between FAI PIC (Andrew) and ENN PIC (Jason) to start the hand-off process. FAI sends permission for ENN hand-off across Iridium.

Hand-off Control: Final handoff checklist performed at each GCS. PIC at FAI reads from checklist and PIC at ENN confirms all details.

Landing: VO at ENN confirms that can see aircraft. Chase plane Heli is called off once the VO can see aircraft and airspace around flight. FAI tracking aircraft via satcom; ENN with 900 MHz and 2.4 GHz. ENN GCS is lead GCS. Touchdown at 16:05 LT (00:05 UTC 8/9).

Post-landed Checklist: FAI GCS went through Sections 1.8, 1.9, and 1.10 of the SeaHunter handbook as the aircraft landed.

Post-flight logbook: PIC at FAI fills it out. There is a flight sheet for all; who was on the flight crew, who the operations were handed over to for landing.

Post-Flight Checklist: Section 1.13 completed - GCS shutdown. Completed by the SIC.

Post-Deployment Checklist: All outside gear is placed back in the trailer. Check all radio's: ALMR and regular before VO communications.

ENN Crew return*:* Arrived back at 17:38 LT (01:38 UTC 8/9). Had left ENN at 16:41 LT (00:41 UTC). Communicated to the team via the group text set up by Day of operations lead.

Debrief: Operations lead for the day lead the debrief. Discussion of issues of the flight and plan out long-term mitigation actions and the effectiveness of those taken on the day.

*Day 4 – September 8*

This day focused on the flight operations from FAI to ENN and back. Brief for the day started at 08:00 LT (16:00 UTC). Focus on crew team members for the day. Described the flight: Climb to 4500 ft due to higher ceilings and the issue of 900 MHz from previous day. Same COA corridor. Hand-off from FAI to ENN at the right turn [2/3 down the COA strip]. Everything needs to be green/100% before landing back at FAI.

*The following details are from recorded notes on execution from team member at the ENN crew site during the exercise.*

Deployment to site: ENN crew left for Nenana at 08:05 LT (16:05 UTC) once brief for days operations completed. ENN crew arrived at 09:11 LT (17:11 UTC). Attached GCS trailer to move to the taxiway for operations.

Pre-flight preparation: ENN crew set-up the GCS, antennas, radio links, generators, and safety cones with sign. Each person has a role (PIC, SIC, VO/crew) to ensure efficient setup. Note that PIC checks with the VO/Eng. crew members to confirm that all items outside are done for a double check of the setup and team redundancy. Pre-flight checklist: Team goes through the setup. PIC as lead and SIC confirming. Checklist followed by the book using SeaHunter handbook. ENN to FAI: ALMR radio check between the two GCS.

Flight operations: 09:40 LT (17:40 UTC) – FAI communicates that started engine check, ready for a 10:00 LT (18:00) departure. FAI GCS checks with the Chase VO, 10 minutes before planned take-off time. 10:05 LT (18:05 UTC): N347UA [UAS aircraft sign] takes off to the North. 10:06 LT (18:06 UTC): FAI GCS communicates to Chase VO. VO confirms has the UAS in sight.

GCS handoff [FAI to ENN route]: FAI PIC leads. ENN PIC/SIC confirm the requests. ENN PIC has a checklist from handbook. Goes by book. ENN PIC reads details back to FAI to confirm. FAI PIC sets the communications to send the control to ENN via Iridium. ENN GCS: PIC on the 900 MHz communications. SIC on the 2.4 GHz communications. Confirm that both have waypoints to track the aircraft.

ENN GCS as lead for landing: 10:20 LT (18:20 UTC): FAI confirms to chase that the handoff to ENN is done. ENN GCS is lead. ENN PIC informs the ENN traffic on the UAS landing upcoming and the route to be taken along with the distance out from ENN. Re-confirms at 9 miles from ENN. ENN VO heads out to track aircraft and airspace once the aircraft is 9 – 10 miles from ENN. ENN PIC (now as lead) informs the Chase of the turn via ALMR radio and altitude for descent. 10:30 LT (18:30 UTC): ENN VO checks in to state in place. ENN PIC communicates to VO on the distance out so that ENN VO is made aware. ENN SIC has headset on in preparation for when lands. 10:32 LT (18:32 UTC): ENN VO has the aircraft in site. Informs the Chase VO.

Aircraft landing: Landing checklist: ENN PIC goes through the list from the handbook. ENN SIC in the GCS confirms. ENN VO is on radio for the landing and to communicate with ENN PIC. Lands safely from the southwest. Taxi to the GCS with ENN SIC using FPV and manual control. Stops taxi at the edge of the taxiway and next to the safety cones. ENN SIC on the controls. ENN VO stays in place for departure. ENN PIC checks the route back to FAI.

Aircraft departure back to FAI: 10:40 LT (18:40 UTC) – Starts departure back to FAI. ENN SIC in control of the UAS. ENN PIC goes through checklist for departure using the SeaHunter handbook. ENN SIC confirms. SIC puts on autopilot for take-off. Successful take off the North-

East. Chase VO confirms to have eyes on the aircraft. 10:50 LT (18:50 UTC) ENN PIC radio communications to ENN traffic that NA347UA is 5 miles out and clear of ENN. ENN PIC in communications with Chase VO of the left turn within the COA corridor. ENN PIC via cell phone to FAI PIC on entering the corridor and 15 miles to the shoulder to start hand-off.

GCS handoff [ENN to FAI route]: ENN PIC leads and reads the checklist directly from the SeaHunter handbook. Once handed off, FAI PIC will be the lead. ENN PIC sends the permission to be lead. FAI PIC confirms has 900 MHz packets. Communications: FAI has satcom, 2.4 GHz, and 900 MHz, while ENN has 2.4GHz, and 900 MHz. FAI PIC confirms that their GCS has 2.4 GHz signal. This is in the checklist. FAI PIC confirms that they have aircraft across all three communications (satcom, 2.4 GHz, and 900 MHz). They are now lead GCS. 11:08 LT (19:11 UTC) – still have good FPV connection at 30 miles from ENN. 11:14 LT (19:14 UTC) – ENN just lost the FPV over 5.8 GHz at 3000 ft altitude on approach as descends to FAI.

Aircraft approach to FAI: Ground VOs at FAI confirm that they have eyes on the aircraft and confirm to chase VO.

ENN post-flight Deployment to Hanger: ENN GCS crew take down of the GCS and follows checklists. Puts all equipment into the GCS trailer including antennas, cables, security barrier items. Left ENN on return to FAI at 11:30 LT (19:30 UTC).

Debrief: Operations lead for the day lead the debrief. Discussion on how the 900 MHz and FPV worked better at the higher altitude. Note that waited until 10:00 LT (18:00 UTC) as this is when the NOTAM went active.

### *2.22.4 Lessons Learned from the Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Functional Exercise, Including Responses to Research Questions*

#### 2.22.4.1 Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Key Findings

1. Knowing the likelihood of the conditions the night before flight operations allows the lead for operations to determine if there is potential for operations.
2. Use of checklists proved absolutely indispensable.
3. Periodic weather checks should occur to check current conditions at take-off and landing as well as along route.
4. Especially when chase aircraft are involved, there needs to be agreement on the terminology to be used between the RPICs and the VO.
5. Last minute changes are not uncommon in the need for certain equipment.
6. All flight crew and ground team utilized websites, radio channels, and applications that they used to determine the weather conditions at the take-off, in-route, and landing sites.

#### 2.22.4.2 Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Recommendations

- Track the weather forecast during the evening before. Evaluate weather from METAR and TAF, if available for site location. Request a spot forecast just before flight take-off and landing as well as along the route. Make an assessment to cancel the flight if conditions indicate no sign of change. If conditions do show indicate signs of change to support operations, perform assessments before team deploys to flight location.

- Equipment issues can (and will) occur at the most inopportune times. When an issue is discovered during the use of a checklist, temporarily halt the checklist until the issue is resolved. Use downtime (as in a weather delay) during the operational day to check equipment and review SOPs and CONOPs for the mission, the UAS, and their payloads to be used.
- Include a check of all components during a pre-flight checklist. Include members of the flight crew who have flown the UAS before as well as a flight crew member who have used the payloads onboard. Experienced team members should support the crew to effectively detect and mitigate any issues and ensure safe flight operations.
- Have detailed checklists. Follow them by the book and have a second crewmember confirm the checklist was completed and all is safe for flight. Follow the checklist, step-by-step, for all missions, irrespective of the experience and flight hours of the crew. Record the checklists were completed.
- The use of call signs can greatly improve the brevity and relevancy of communications. Define all call signs before flights occur. Determine the call signs for the GCS and RPIC as well as the chase aircraft, if used. Include identifying these call signs in the SOP, CONOPs and checklists, where necessary. Include this information in first brief of the day and ensure any updates are passed along to all in flight crew and ground team.
- Ensuring that all available UAS are ready to operate (fueled up, batteries charged, payload checked) allows the flight team to adapt to needs of operations and complete the mission as required.
- Use downtime during the operational day to check equipment and review SOPs and CONOPs for the mission, the UAS, and their payloads to be used. Ensure team is ready to fly, when the conditions support safe operations, and the team is optimized to use weather windows to complete operations in NAS.
- Ensure flight crews and ground teams are aware of allowances of flight altitude due to weather constraints (ceiling) and permissions (COA). Ensure that local knowledge can be adapted into flight operations while ensuring all SOP are adhered to and checklists followed. Take note of previous flights along the same route and adapt the flight route, within constraints, to mitigate issues and ensure safe operations.
- Ensure all crew and ground team are aware of risks to the mission and are briefed on action plans to mitigate any hazards to safe operations. Keep the ORA up to date and have all crew and ground teams aware of backups for safe operations and mission action plans.
- Ensure the site lead for operations is aware of condition changes so they can make informed decisions for go/no-go actions. Follow SOPs and CONOPs for decision making processes to determine if flight operations will continue. Have specific sites/apps that flight crew use and include these in SOP and CONOPs so that comparable information can be reviewed by all crew members. Crew and ground teams also should assess weather conditions at site for take-off and landing as these may be different from METAR and TAF, given the CGS could be distanced away from airport where the METAR or TAF is provided

#### 2.22.4.3 Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Informed Research Questions

1. N/A

2. Knowing the likelihood of conditions the night before flight operations allows the lead for operations to determine if there is potential for operations. This will ensure optimal use of the flight crew to support flight operations. Should adverse weather exist the crew and ground teams can accomplish other activities rather than waiting until the weather conditions improve optimizes their time, especially if the conditions are known the day before and show no options for safe flights on the proposed flight date.
3. During the checklist of the UAS and payload, including First Person View (FPV) camera, an issue with the FPV camera was found. This was resolved by the flight crew and ground team to ensure that the data feed provided a clear signal for the flight operations. The team followed the checklists using the OEM handbook, with confirmation by a second flight crewmember. Team members with experience in flying the lUAS were able to resolve the issues and support the team to continue the pre-flight checks.

   While conducting checklists, pre, during, and post-flight, the RPIC and SIC followed a checklist directly from the UAS handbook. One flight crewmember performed the checks and a second confirmed. This was done at both the GCS as well the hand-off when the RPIC at one GCS read out the checklist and the RPIC at the second GCS confirmed that the checks were completed. Following the handbook checklists allowed the flight crews to resolve any issues, such an issued detected with the 900 MHz communications at the second GCS. Here, the crew did not progress with their checks until the issue had been resolved.

4. Weather can cause delays as conditions prevent safe operations. Periodic weather checks should occur to check current conditions at take-off and landing as well as along route. During weather delays, these gaps can be used to run through checks of the equipment and keep all team members up to date on operational mission so that team is ready to operate when the time comes.

   During the exercise, there were two GCS and a VO in a chase helicopter. This meant there needed clarification on the terminology to be used between the RPICs and the VO. The team determined FAI, ENN, and CHASE would be used as call signs between the separate groups. This ensured there was clear communication as to who was talking on the radios during flight checklists and flight operations. Around busy airports, it is essential to have clear call signs to minimize any confusion.

5. This exercise was to fly from a large international airport to a small non-towered rural community airport and back. This larger airport was in Class D airspace. Therefore, when an issue was identified and for safety of the flight, then mitigation plan was to return to the smaller non-towered airport for a landing. The CGS crew and ground team at the Class D airport stayed in place until the UAS landed at the rural airport to support this action plan, if needed. All crews were aware of the mitigation plan to ensure safe operations and to minimize the risk of flying the lUAS into the Class D busy airspace, if the UAS was not operating properly.
6. Given the mission, there may be issues with the UAS proposed to support the flight operations and/or a different payload required. Ensuring that all available UAS are ready to operate (fueled up, batteries charged, payload checked) allows the flight team to adapt to needs of operations and complete the mission as required. Also, providing the flight crew with a range of spare components that can be called up, if needed is essential.

7. Flight operations started with a briefing at the hangar location before the two ground control stations, crew, and ground teams deployed to their locations. At one airport, there was additional taxiway engineering work occurring that required contacting the local international airport operations to receive an escort across the engineering work to reach the GCS site. On the day of the proposed operations, the site lead contacted the airport to obtain access and was informed of prohibitive security issues. Access was eventually granted.
8. Weather conditions and specifically cloud ceilings can limit safe flight operations, especially when ensuring that mission follows COA requirements and VLOS operations. Flights on the previous day had been weather restricted in the allowable altitude. As such, there had been issues with the 900 MHz signal and the FPV feed to the GCS in command. Therefore, a decision was made to fly at higher altitude, weather and COA permitting. Here, the flight crews adapted their knowledge from previous flights, along with knowledge of SOP and allowable operations to ensure communications between UAS and GCSs.
9. N/A
10. During the day's operations, the flight conditions changed as the day progressed from the first brief to the original planned flight time and beyond. All flight crew and ground team utilized websites, radio channels, and applications that they used to determine the weather conditions at the take-off, in-route, and landing sites. The site lead for operations had their specific application and continued to use the same tool to make assessments on the changing weather, using the METAR and TAF when available. In addition, they examined the weather conditions by looking at the sky and wind direction to determine the conditions real-time.
11. N/A

#### 2.22.4.4 Pandemic: Medical Delivery Between Major Hub and Rural Community (IUAS) Lessons Learned Summary

It is critical to assess weather conditions well in advance of the operation and be ready to cancel flights if conditions are unfavorable. To enhance coordination, maintain a contact database to keep all stakeholders informed of mission adjustments. During operation postponements, conduct equipment checks and ensure the team is well-informed about mission constraints and modifications, optimizing readiness for favorable weather windows. Strict adherence to OEM and institutional checklists is essential at every stage of the operation. Lastly, emphasize clear communication with team members to ensure adherence to procedures and increase both safety and efficiency.

## 2.23 9/23/2023, Functional Exercise, Pandemic: Medical Delivery Between Rural Communities (sUAS), Bethel, AK, Conducted by UAF

Amid a pandemic crisis, a remote rural community finds itself critically undersupplied, with no viable road access available. The only lifeline is through airborne transport, but even this option is hampered by adverse IFR conditions, rendering crewed flight systems inoperable. Additionally, the local river, typically a vital transportation route, is rendered unsafe due to the presence of thin ice and hazardous ice blocks.

**Note:** This was adapted to be a flight operation between two locations within the Community of Bethel.

### *2.23.1 Objectives of the Pandemic: Medical Delivery Between Rural Communities (sUAS) Functional Exercise*

The objectives of this functional exercise were for local medical health organizations to define locations within the community of Bethel where UAS operations can support them during day-to-day operations. Local community Part 107 pilot is to operate a sUAS between locations within the community of Bethel to build towards community missions that couple local pilots and community organization needs for potential pandemics that limit ground movement.

Major goals were:

- for a sUAS to be flown within the community of Bethel following site selection by local health organization. (The mission will be flown under Part 107 VLOS operations.)
- for the local pilot to use checklists to ensure safe flight operations from pre-deployment to flights and to post-flight and post-deployment.
- to demonstrate that a community could provide sUAS that bring together local Part 107 pilots and organizations with needs during a future pandemic event.

### *2.23.2 Planning for and Logistics of the Pandemic: Medical Delivery Between Rural Communities (sUAS) Functional Exercise*

Site Visit (August 31 – September 3, 2023)

Prior to trip

The ACUASI team met up via Zoom with Adam Low and Brian Reggiani from the UAF Teaching through Technologies (T3) program and also as the leads of the UAF Upward Bound (UB) program. Introductions were made to the T3 and UB site team that has a student team in Bethel at the local high school, including a drone club and a Part 107 pilot. The ACUASI team also met up with Gabriel Low, who would lead the T3 Labor Day training for the UB/T3 students and teachers in Bethel coinciding with the site survey and visit. Gabriel is also connected to the teacher and planned Part 107 pilot and provides useful details on discussing the flight that the pilot would complete.

Site Assessment

*Day 1: Thursday, August 31st*

The site survey and assessment team traveled to Bethel (BET). The team met Brian Lefferts, Yukon Kuskokwim Health Corporation (YKHC), in his office to explain the visit and to talk more on the sites that he had provided to the team. Brian spoke about needing to move supplies between the hospital and the warehouse and this would be an option. Also in some small communities, the runway and the clinic are on different sides of the river, and so the flights would be equivalent to a mission to move supplies in a smaller rural community and during times when personnel cannot cross the river. The team walked over with Brian to the roof of the hospital main building, Brian was able to provide the team with access to the roof of the main YKHC hospital to take photos and assess flight locations. The photos below provide an overview of the likely flight direction for the Part 107 pilot. This is towards the YKHC warehouse. The pilot could fly from the roof of the building, then parallel to the utility lines, follow the curve of the side road, and across the landscape to the warehouse. The site team visited the warehouse, where the Part 107 sUAS would fly to during its mission. Hazards were identified and mitigated, for example, the powerlines in the flight path will be flown over. A crucial aspect of the visit and the survey was to identify hazards and to make the local pilot aware of the issues. This allowed the site assessment team to review the site for the UAS to land and where a visual observer could support the pilot for VLOS during the flight. The site survey team would meet with the pilot on Friday September 1st to talk through the flights.

*Day 2: Friday, September 1st*

This day was focused on meeting Jeremy, PIC, and James, Mentor, at the local high school, Bethel Regional High School. The site survey team used the morning to develop additional questions to ask Jeremy and James. Thoughts included talking to Brian to get to the flight sites to see and assess the route, along with giving options for weather impact and/or delays. PIC spoke about the aspects of his current flights: check batteries, check aircraft, ensure a safe site for take-off and landing, inform all at the site of the flight details, and talk to VO's and how to communicate during flight.

*Day 3: Saturday, September 2nd*

This day was focused on the T3 training at the UAF Kuskokwim Campus where the site assessment team could talk more with Jeremy and James as well as meet other T3 and UB programs. During the day, the site assessment team got to talk to Jeremy, where they spoke with him on general components for best flight practices. Question to Pilot: What limits you to fly? Response: Require VLOS. Jeremey wants to see the flight area. Site assessment team put him and his teacher James Reames in touch with Brian at YKHC.

*Day 4: Sunday, September 3rd*

The team spent the morning with the T3 training. Site assessment team, after talking to the teacher, to acquire a Remote ID compliant UAS for the UB/T3 club so that they would be able to fly after September 16, 2023. The team left to return home to Fairbanks.

#### ***2.23.3 Pandemic: Medical Delivery Between Rural Communities (sUAS) Functional Exercise Execution***

Flight operations occurred on September 23, 2023. ACUASI-UAF team along with partners from KSU were in Bethel, Alaska to observe the flight operations to be completed by the local Part 107 pilot.

*Pre-deployment: Pilot and Mentor Briefing for Missions*

The mentor for the mission, Teacher Reames, started off the briefing. The mentor explained the significance of the weekend and the planned operations. They passed over to the PIC to provide the pre-deployment briefing to all the team (including those to be located on the roof for the take-off, the spotters/VO along the route, and the team to be at the warehouse landing site). All additional members attending the briefing were able to determine where they could view the operations and who was responsible and lead for the flights. There will be two spotter/VO locations. There will be one person, the VO, at each site with an orange jacket on so that all can see who is the responsible VO. There will be a landing zone crew at the warehouse.

*Pre-flight setup*

All those flight crew members including A52 project team members and collaborators were staged on the ground floor of the hospital. Mentor for the mission informed all of those who could travel with the flight crew to the roof. All of those at the warehouse landing zone and two VO locations headed to their sites while the flight crew setup in the hospital. All able to visit the roof for the take-off and return followed the flight crew. Lead for the mission briefed all spotters/VOs via radio. Spoke about the public and the crew including the VO's and who will keep away anyone wanting to get involved in the mission. While pre-flight briefing occurs, all others move onto the roof. Assistant at the take-off site informed all of those on the roof of the process and planned mission.

*Flight process*

| | | |
|---|---|---|
| 16:04 LT | 00:04 UTC 09/24/23 | Lead on day asks all to head to roof. |
| 16:10 LT | 00:10 UTC 09/24/23 | Roof crew head out. |
| 16:15 LT | 00:15 UTC 09/24/23 | PIC briefs crew, A52 team member watches. |
| 16:15 LT | 00:15 UTC 09/24/23 | Lead on day briefs all who will go onto roof. |
| 16:20 LT | 00:20 UTC 09/24/23 | Public observing the flight go onto roof. |
| 16:25 LT | 00:25 UTC 09/24/23 | Radio Check. |
| 16:30 LT | 00:30 UTC 09/24/23 | Flight occurs. |
| 16:42 LT | 00:42 UTC 09/24/23 | All flight team and observers return to post-flight location. |

Note at 16:17 LT (00:17 UTC 9/24/23), A52 observer performs own weather check. METAR shows from 15:14 LT (23:17 UTC) that airport had 7 SM visibility, light rain, broken clouds at 1300 ft. A52 team member notes that setup on the roof and the proximity of those observing to the location of the PIC and VOs. Lesson learned for future missions and other Part 107 pilots. Successful flight.

*Post-flight*

Lead for the day, Teacher Reames, informs all observers where to head towards for the post-flight setup. PIC and crew performed their own post-flight debrief before joining all the observers and mission team members from the VO sites and warehouse landing area. Lead for the day spoke to all the attendees on the outcomes of the mission.

### *2.23.4 Lessons Learned from the Pandemic: Medical Delivery Between Rural Communities (sUAS) Functional Exercise, Including Responses to Research Questions*

#### 2.23.4.1 Pandemic: Medical Delivery Between Rural Communities (sUAS) Functional Exercise Key findings:

1. Bethel is a hub community that can link to 50+ smaller villages, but it has a significant footprint where residents can be cut off in the winter from medical supplies. Weather review before flight briefing starts will allow PIC Part 107 pilot to assess if the local conditions support the planned operations.
2. The PIC should confirm to the VOs on the terms to use to ensure that all understand commands.

3. A clearer zone for the PIC and VOs would have better supported the flight operations. Given the weather conditions, it was difficult for observers to see the location of the PIC and VOs.
4. Statewide cell service (GCI) was reliable in rural Alaskan communities.
5. First responders must be compliant with remote ID requirement for Part 107 and potential future FAA regulatory changes.
6. Ensure safe and legal operations for all Part 107 pilots.
7. Wind speeds provided at the local airport may be very different from UAS flight locations.
8. In some regions of the country, there may be a scarcity of local Part 107 pilots to support operations. As more rural communities look to expand the number of Part 107 UAS pilots then more opportunities to complete their exam in their community rather than having to travel out of the region are needed.

#### 2.23.4.2 Pandemic: Medical Delivery Between Rural Communities (sUAS) Functional Exercise Recommendations:

- There are opportunities to build a database of scenarios where drones could make a big impact on the safety of local populations. CONOPs that could be used in the advent of an event would be helpful to support rapid response where eligible pilots with the aircraft could support the emergency services.
- Flight team, especially operational lead and/or PIC include updated weather condition analysis in the pre-deployment and pre-flight checks. Also have the PIC include standard operating procedures for missions and ensure all on team is aware of these policies.
- Flight checklists, including pre-flight briefing, should include reconfirmation of the terms to be used.
- sUAS operations have a clearly defined area for PIC and VOs so that all observing can delineate an area to stand.
- Under the prevailing weather conditions of this exercise, sUAS operations should have a clearly defined area for PIC and VOs so that all observing can delineate an area in which to stand. Under extreme weather conditions, the PIC must conduct an assessment just before the flight to ensure they are ready to perform safe flight operations.
- Flight crew should have a pre-flight weather assessment at all possible locations over the mission to determine if a delay would be a benefit.
- Ensure that the flight crew has reliable phone/satellite/Starlink communications, has informed the central group that they are going to perform operations, and have backup communication capacity.
- There is a need for spot weather data at the take-off, landing, and along the route.
- In communities with few Part 107 qualified PICs, find individuals who can become Part 107 pilots then the local school and/or community organization is an appropriate environment to foster the interest and train new pilots.
- Collaborate with local organizations and school districts to find eligible individuals to become Part 107 pilots.
- Have FAA Part 107 teams working with local community organizations to provide Part 107 exam certification opportunities in the local community.

- Ensure that there is clear outreach to all Part 107 remote pilot certificate holders well in advance so that they are aware of changes upcoming and can ensure they comply for safe and legal flights.

**2.23.4.3 Pandemic: Medical Delivery Between Rural Communities (sUAS) Functional Exercise Informed Research Question(s):**

1. N/A
2. N/A
3. A52 team members observing the operations did weather checks at approximately 13:00 and 15:00 LT (21:00 and 23:00 UTC) and noted that the weather conditions showed light rain in the vicinity as well as a low cloud ceiling (15:00 LT, 23:00 UTC showed broken clouds at 500 ft from the METAR). PIC and mentor started the pre-deployment briefing to inform all persons involved in the mission of the planned operations and the significance of their roles. Additional weather analysis also supported flight team to determine if a delay would support operations.

   With small communities, the number of potential Part 107 pilots connected to the UAS industry will be small. A community of 300 or so will have a smaller number in the school and often have several years together in one class. Therefore, to find individuals who can become Part 107 pilots then the local school and/or community organization is an appropriate environment to foster the interest.

4. Parts of the community near the airport are a significant distance from the local hospital and winter weather conditions, i.e., snow drifts, can prevent residents from getting to hospital and the emergency services reaching them. Drones could provide rapid support during the wintertime. This type of CONOPs represents a need for a community like Bethel where small-scale hazards can significantly impact the safety of the community.

   PIC and VOs were together on the roof and there was safety tape on the edge of the roof to protect all outside. There was also a table and small cones to provide a cockpit area for the PIC and VOs. A clearer zone for the PIC and VOs would have support the flight operations. Given the conditions, it was difficult for observers to see the area set aside for the PIC and VOs.

5. N/A
6. There is a growing interest in the use of UAS across the U.S. and individuals who want to obtain their Part 107 remote pilot certification travel to specific FAA test sites to complete the exam. As more rural communities look to expand the number of Part 107 UAS pilots, more opportunities to complete their exam in their community rather than having to travel out of the region are needed.
7. With new changes to come into rule on September 16, 2023, all pilots need to have remote ID capabilities on their UAS and have several options on how to ensure that their aircraft follows the rules: https://www.faa.gov/uas/getting_started/remote_id. Part 107 pilots will complete their remote pilot certificate exam, but how do they find out about new rules changes, especially ones like the Remote ID?
8. Statewide cell service (GCI) was reliable in rural Alaskan communities while national provider American Telephone And Telegraph (AT&T) did have some service, but it was poor, slow, spotty, and when a strong storm came through there was no service and the phone stated “SOS’ calls only. Note: that prior to travel, the team had found that AT&T would not work and were

surprised to see it did, even though slow and not reliable. GCI worked all the time and was used for navigation to certain buildings to meet community members.

9. N/A
10. PIC was lead for operations. VOs were aware of the terms to use so that the PIC could assess safety of the operations. PIC had to remind them to use clear speech and the correct terms. Before a flight, it would be good to check that all are aware of the correct terms to use so that it does not need to be confirmed just before flight.

    There is a growing interest in the use of UAS across the U.S. and individuals who want to obtain their Part 107 remote pilot certification travel to specific FAA test sites to complete the exam. As more rural communities look to expand the number of Part 107 UAS pilots then more opportunities to complete their exam in their community rather than having to travel out of the region are needed.

11. N/A

#### 2.23.4.4 Pandemic: Medical Delivery between Rural Communities (sUAS) Lessons Learned Summary

It is critical to assess weather conditions well in advance of the operation and be ready to cancel flights if conditions are unfavorable. Understanding community capacity and identifying the available pilots is essential to support missions between rural communities. During operation postponements, conduct equipment checks and ensure the team is well-informed about mission constraints and modifications, optimizing readiness for favorable weather windows. Lastly, emphasize clear communication with team members to ensure adherence to procedures and increase both safety and efficiency.

## 2.24 10/19-24/2023, Drill, Landslide, Smuggler's Notch, VT, Conducted by UVM

UVM carried out this drill to investigate the challenges and opportunities that arise from the integration of sUAS into disaster preparedness and emergency response plans for landslides. Landslides are a common occurrence in Vermont with recorded instances of repeated slips. UAS deployment has many benefits, including the ability to collect real-time information from areas that are either too difficult or dangerous for humans to reach and provides a means of evaluating land surface change over time. Both tasks aid efforts to assess hazards and mitigate risks at these sites. However, areas commonly affected by landslides also pose significant challenges to drone deployment due to high topographic relief, remote locations, inclement weather, and/or sparse infrastructure. These issues, which can impact all stages of drone deployment from pre-flight planning to post-flight data processing, must be addressed before many of the benefits of using sUAS can be achieved.

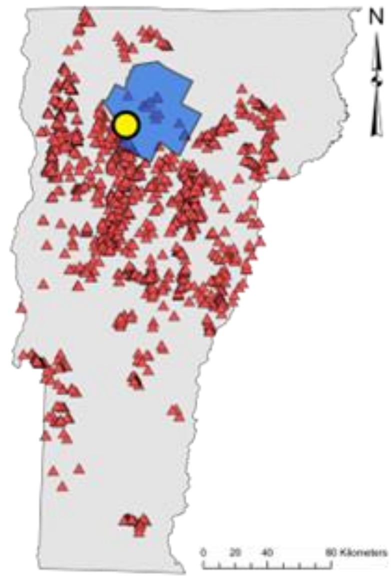



Figure 35. Map of 3049 known landslides (red triangles) in Vermont (after Kim, 2018). Drill site at Smugglers Notch (yellow dot) located in Lamoille County (blue polygon). Source: State of Vermont Open Geodata Portal.

### *2.24.1 Objectives of the Landslide Drill*

The objectives of the landslide drill were to operate UAS to collect oblique images, true-color mapping imagery, and LiDAR data in response to landslide activity. The UAS oblique images documented the context of the landslide site and the surrounding environment, mapping imagery was processed into an orthomosaic map, and LiDAR data was utilized to generate accurate elevation models of the area. In addition to data collection and data products, another objective was to identify the challenges and opportunities that arise from the integration of UAS into landslide response.

### *2.24.2 Planning for and Logistics of the Landslide Drill*

Initial planning involved selection and review of a suitable site. The location selected for this drill is within Smugglers Notch, VT. Rockfalls and other forms of slope instability have occurred at Smugglers Notch for thousands of years. Most recently, major slides happened in 1870, 1910, 1983, 2020, and 2021 (Baskerville et al., 1993; Springston, 2009; Kim et al., 2023). Geological work suggests that there are two main types of slope failures at the site. The first is rock falls and rockslides, which involve large pieces of rock detaching from a cliff and falling, bouncing, or sliding down the slope (Springston, 2009). Some fallen blocks are more than 10, 000 tons (Baskerville et al., 1993) (Figure 36). At least one that fell in 2020 displays rock climbing equipment embedded in it, which calls attention to its impact on recreational climbing areas and can be used to help track where the block originated (K. Klepeis, 2020). The second type of instability is debris flows, which are slurries of water, mud, pebbles, cobbles, and boulders that flow within channels on the talus slopes below the cliffs (Springston, 2009). Both types of instability are promoted by heavy rainstorms, which often occur between the months of May and

December. Other contributing factors include high topographic relief (~300 meters), freeze-thaw cycles, root wedging, surface and groundwater flow, and gravity, all of which act on fractures and other geological structures that occur naturally in the bedrock to cause slope failure. These failures are predicted to increase in frequency in coming years because of climate change.

Figure 36. Vehicle damaged by a fallen boulder at base of Hidden Gully debris flow path along VT 108. May 31, 2020. There were no reported injuries. (Photo: Vermont State Police).

The physical environment at Smugglers Notch creates challenges that work against the effective and timely deployment of sUAS equipment. Alpine weather in northern Vermont is often unstable and unpredictable. This variability can result in the sudden appearance of fog, haze, low clouds, and heavy rain or snow at any time of the year, which can lower cloud ceilings and limit visibility to less than 3 statute miles. The area most prone to slope instability at the notch forms an amphitheater of cliff faces that are higher on the northwest side than on the southeast (Figure 37). This asymmetry, combined with the high topographic relief (650 to 1100 meters), increases the probability of downdrafts and localized zones of wind shear that can inhibit flying and can be difficult to predict on site. The high elevations and variable temperatures also can result in increasing or high-density altitudes, which decreases the efficiency and performance of wings and propellers. Lightening from thunderstorms and high winds create additional risks. All these factors highlight the need for efficient pre-flight weather planning as well as a well-defined decision-making plan to address situations that arise unexpectedly onsite.

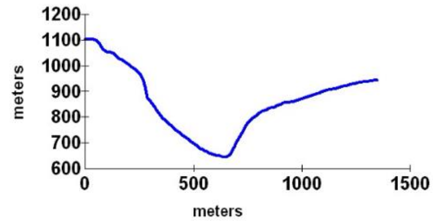



Figure 37. Topographic profile across Smugglers Notch showing the asymmetry of the narrow pass (after Springston, 2009). The northwest side, where much of the landslide activity occurs, is on the left, southeast is to the right.

Smugglers Notch is accessible by motor vehicle along only one road (Vermont Route 108) that narrows into a single lane at the notch itself. This narrow pass, along with its remote location, inhibits response times and promotes traffic congestion during times of peak activity in late summer and fall. The road is impassable in winter and cannot accommodate single vehicles longer than 40 feet or vehicles with trailers that are longer than 45 feet. A small (~20 vehicle) parking lot and rest area occurs near where the road is the narrowest, which can exacerbate congestion as tourists and other travelers congregate. Curious onlookers create another potential challenge, if not managed carefully, because they can distract UAS personnel and cause drone operators to inadvertently fly over people.

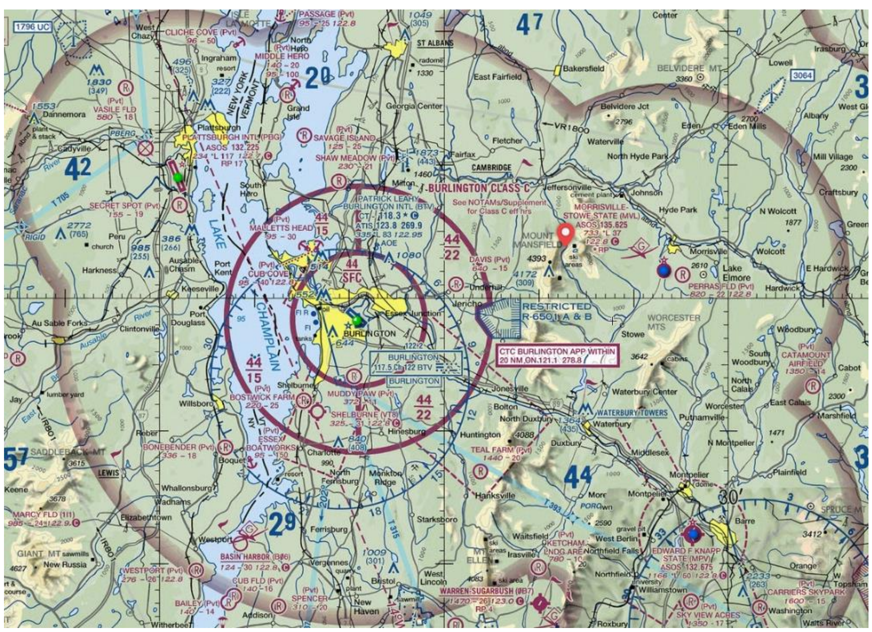



Figure 38. The red pinpoint symbol indicates the approximate location of flight operations in Smugglers Notch State Park.

The remote location, limited infrastructure, and seasonal high traffic accentuates the need for coordination among groups most likely to be involved in disaster response. These groups include state park officials (Smugglers Notch State Park), business representatives (e.g., Smugglers Notch Ski resort), VTrans personnel (road management), SAR crews (e.g. Vermont State police, Stowe

Mountain Rescue), geologists from UVM, the Vermont Geological Survey, and Norwich University along with SAR personnel and, potentially, the news media. Cell service is either absent or limited in the region. Developing a mechanism for effective communication among responders and other groups dispersed at the site is essential for safe, effective management of these different groups both on and off site.

Potential risks and challenges associated with flight operations were identified. The physical environment at Smugglers Notch, consisting of a nearly vertical 1000ft cliff band, poses operational challenges such as limited VLOS, unpredictable weather, and steep vertical terrain. At this location, fights during leaf-on conditions would prevent the RPIC and VOs from maintaining VLOS, therefore operations were scheduled for the fall of 2023 during leaf-off conditions. As mentioned previously, the site has unstable and unpredictable alpine weather which can lower cloud ceilings and limit visibility (Figure 39). There is also an increased probability of downdrafts and localized zones of wind shear that can inhibit flying.

Figure 39. Low clouds passing through the flight area in July 2023. This negatively impacts visibility and creates unsafe sUAS operating conditions.

The collection of data in areas of complex topography, including cliff faces, comes with inherent challenges. Steep faces commonly are source regions for falls and can be difficult to image well using nadir mapping techniques, which often results in data gaps on the steep faces. Oblique mapping approaches typically are preferable and may require sophisticated pre-flight planning. The complexity of the terrain, weather conditions, and other factors also may require manual flying rather than using automated flight plans in some cases.

Another problem common to sUAS mapping in alpine environments centers on the georeferencing of images, point clouds, and other data. Adequate georeferencing of digital data is essential because the assessment of hazards and risk at landslides often requires careful measurements of the orientations and dimensions of geological features. Repeat surveys also are desirable to measure landscape change over time, identify areas of the highest risk, and to aid predictions of future events. However, limited cell tower visibility complicates these efforts. This limitation, for example, can preclude the use of RTK approaches and instead can require the use of a base station and/or ground control points for PPK. Cold temperatures also impact battery life and can limit the size of mapped areas.

The choice of sUAS equipment, including drone payload types, is an important consideration. Typically, tree canopy is a problem because fallen debris and talus slopes may be vegetated, which can limit the ability to locate and measure features accurately (Figure 40). LiDAR systems offer the ability to see through this cover to the ground surface below. However, this equipment significantly raises the cost of sUAS operations and may complicate pre- and post-flight workflows.

Figure 40. Steep cliff faces located at the site, which complicate flight planning and data collection.

Oblique imagery and video collection would be carried out via manual control of a small multirotor. The UAS platforms selected were the DJI Mavic 3 and DJI Avata 2. The Mavic 3 includes an integrated true-color camera. The Mavic 3 was used to collect oblique images and scope out the area, including areas with line-of-sight challenges, before automated mapping. The Avata 2 also includes an integrated lower resolution true-color camera, intended for video capture over image capture. The Avata 2 can also be paired with an FPV headset, which allows for a unique real-time perspective of the area of interest.

True-color mapping would be completed via automated mapping missions with a multirotor UAS. The platform selected was the DJI Matrice 300 RTK equipped with the DJI Zenmuse P1 24mm sensor. The flight plan was designed in UgCS flight planning software using the photogrammetry tool to collect true-color mapping imagery at or under 400ft at a speed of 10 meters/second with lateral and longitudinal overlaps of 75% between images to ensure adequate stitching for photogrammetry. Two routes were created, the first capturing images at a 25° angle and the second capturing images at an 85° angle, to collect the best data possible of a steep area (Figure 41). In both instances, the orientation of the sensor was set to a fixed orientation, so the UAS faced the cliff faces and slide paths throughout the flight. This was accomplished by setting the yaw of the platform to 280° from the north (nearly a direct west orientation) in the flight planning software.

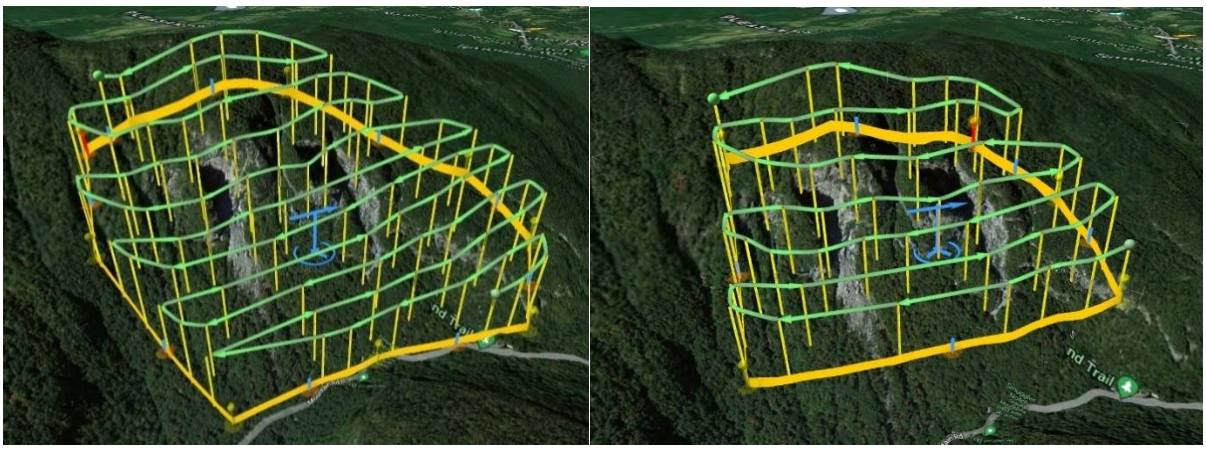


Figure 41. The imagery flight area is outlined by the yellow polygons, with the green lines representing the path of the UAS. Terrain following was utilized to ensure the platform remained at a consistent height above features and avoided obstacles. The left image depicts the flight plan for the full area, with the true-color sensor set to an 85-degree oblique angle. The right image depicts the flight plan for the steeper area, with the true-color sensor set to an oblique angle of 25 degrees. In both instances, the yaw has been adjusted so that the sensor faces the landslide the entire time.

These routes utilized a terrain-following function in UgCS called Smart AGL. Using Smart AGL, the flight plan is designed to maintain the designated flight height, in this case 400ft, in distance away from the terrain in both horizontal and vertical orientations. Interpretation of Part 107.51 (b), under the assumption that a vertical cliff face represents 'ground level,' provided for the generation of flight plans within a 400ft horizontal distance to the cliff face. The difference in utilization of this specific flight planning feature is demonstrated in Figure 42.

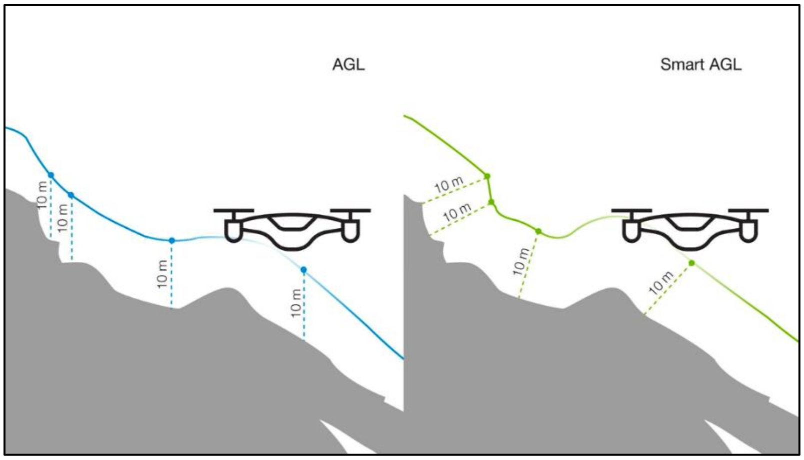



Figure 42. Illustration of UgCS Smart AGL flight planning capabilities in steep terrain. (Image: SPHEngineering).

LiDAR collection were also carried out via automated mapping missions with a multirotor. A mission was designed using UgCS flight planning software for the Matrice 300 platform and the Yellowscan Surveyor Ultra LiDAR sensor using the LiDAR Area tool. The YellowScan Surveyor LiDAR sensor was selected as it can collect data across a 360° swath, with the intent of minimizing coverage gaps within the resulting 3D models on steep vertical or overhanging surfaces. Two flight segments were created, both set to collect at approximately 230ft AGL at a speed of 5 meters/second. The side overlap for both segments was set to 70% to allow for enough overlap between the captured data for processing. The first segment covered the lower half of the flight area and was set to fly in a double grid (perpendicular), to increase penetration where the tree canopy was the densest. The second segment was not a double grid, to improve flight efficiency at higher altitudes where there were not as many trees present (Figure 43). For efficiency over the steeper areas, flight lines were planned perpendicular to the slope, which avoided excessive climbing and conserved battery life. This flight plan utilized the same Smart AGL terrain following feature as the true-color flight plans.

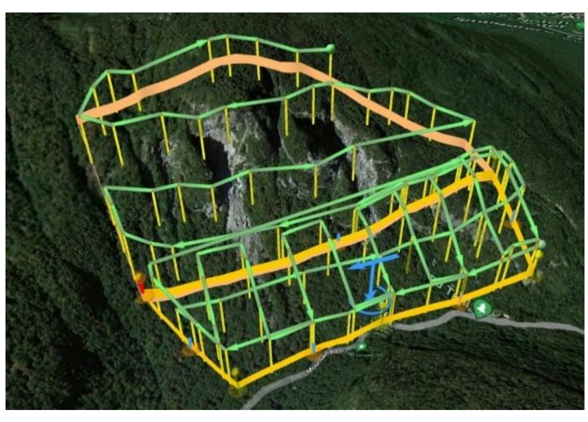


Figure 43. The LiDAR flight area is outlined by the yellow polygons, with the green lines representing the path of the UAS.

### *2.24.3 Landslide Drill Execution*

Prior to executing the drill, the UVM UAS Team utilized their standard UAS operating procedures and protocols, including receiving UVM Emergency Management approvals and notifying VTrans of flight operations and location.

When the team arrived on site on October 19, 2023, the staging area was chosen based on its distance from busy areas of the park and line of sight to the flight area (Figure 44). This area allowed enough room for launch and landing of the UAS and with minimal foot traffic in the area, including trails. This staging location also allowed a comprehensive view of the flight area for the RPIC. VOs were deployed to support the RPIC and to provide situational awareness (SA). VOs would communicate to the RPIC via radio if there were any concerns with airspace, obstacles, or non-participants entering the flight area. One member of the crew was designated to interact with the public to prevent distractions to the RPIC and VOs. This person was able to answer questions about the flight and to instruct pedestrians to avoid the flight area. There were also UAS in flight signs posted on either side of the flight area and traffic cones used to designate the staging area.


Figure 44. Although two parking lots were available, the team chose to stage at the parking lot further from the visitor center to limit disruption to park visitors.

Pre-flight checklists developed through the application Fulcrum were used to assess factors such as weather conditions, risk identification and mitigation, confirmation of platform and sensor airworthiness, among other items before beginning flight operations. Checks included verification of weather in compliance with Part 107 regulations and platform limitations, identification of potential in-flight obstacles, tasking of roles and locations for RPIC and VOs, confirmation that radios were working properly, and reviewing planned emergency procedures. Next, custom checklists designed for the designated platforms, sensors, and software were completed to verify that the systems were properly prepared for flight. These checklists were completed in the field by the PIC with assistance from the VOs using an Apple iPad Mini. The UAS missions included manual oblique imagery and video collection, automated true-color mapping collection, and automated LiDAR collection.

The flight crew completed pre-flight checklists for the DJI Matrice 300 and uploaded the UgCS flight plan to the controller. The RPIC used the DJI Pilot app to check for any warnings and to confirm risk mitigation settings such as return to home height and use of obstacle avoidance. The team also powered on the Yellowscan Surveyor Ultra and confirmed that all status lights on the sensor were displaying that it was ready for collection (Figure 45). After several minutes, the sensor had not yet gained sufficient Global Navigation Satellite System (GNSS) signal, likely due to the topography of the area and the location of the staging and launch site in a valley. To troubleshoot this, the RPIC launched the UAS twice and sent it directly upward to the flight height of 230ft AGL and allowed the UAS to hover there for 1-4 minutes to see if the GNSS connection would stabilize at a higher altitude. Before and in-between attempts, team members checked that the GNSS cable and antenna connections were secure and tried power-cycling the sensor. After the second launch, the GNSS status was sufficient, and the RPIC was able to begin the automated LiDAR mapping mission.

Figure 45. RPIC prepares LiDAR sensor for data collection.

The first LiDAR flight began at 14:33 EDT. The RPIC performed a J-hook maneuver before beginning the automated flight path in order to calibrate the Surveyor Ultra IMU, as recommended by the manufacturer. During the flight, the RPIC and VOs paid attention to any obstacle warnings, high wind notifications, changing weather conditions, non-participants in the area, and other safety concerns during the flight. The RPIC paused the automated mission plan with 40% battery remaining and landed the UAS after completing a second J-hook calibration maneuver. The RPIC instructed the flight crew to immediately switch batteries before continuing with the second LiDAR collection flight at 14:52 EDT. The total active flight times were approximately 16 and 23 minutes for the two flights, respectively.

The LiDAR sensor battery was not exchanged between flights. This decision was influenced by the challenges experienced gaining GNSS connection to the LiDAR sensor before the first flight, to prevent a need to go through those troubleshooting steps again. However, when the UAS landed after the second flight, the Surveyor Ultra was beeping, signaling a low battery. The team pressed the button on the Surveyor Ultra to begin copying the data from the sensor onto the USB drive, which would allow data transfer onto the field laptop. As this data was copying, the sensor battery died. The RPIC copied the data from the USB drive onto the field laptop and opened the file in the Yellowscan CloudStation software to determine whether any data had been lost due to the premature battery death. The file opened successfully, and the entire trajectory was visible, therefore the RPIC determined that the data had still been gathered and copied correctly and chose to continue with subsequent flight profiles.

The team swapped the sensor on the Matrice 300 for the DJI Zenmuse P1 camera and went through all necessary pre-flight checks. The PIC began the flight capturing photos at an 85° angle first, at 15:36 EDT. The 25° sensor angle flight began at 16:09 EDT. Both flights were approximately 23 minutes in length and captured around 340 images each. After both flights were complete, all images were copied from the sensor's SD card onto the field laptop for verification of the number and quality of the images.

With the primary objectives related to LiDAR and orthoimagery capture complete, the team carried out flights with a DJI Avata 2 and DJI Mavic 3 small multirotor to capture oblique images and videos of the landslide paths and cliff bands. These oblique images captured wide and detailed views of the slide areas and its surroundings for context as well as better visualization and detailed analysis (Figure 46). Manual flight during these initial flights allowed the pilot to maneuver the UAS to beneficial viewpoints and capture the rockslide from a variety of angles and distances, and to evaluate line of sight before the automated mapping missions. Oblique images from the Mavic 3 were captured in JPG + RAW format, while videos were collected in MP4 format with accompanying SRT-format subtitle files providing metadata. Videos captured by the Avata 2 were collected in MP4 format.

Figure 46. Oblique images captured by the DJI Mavic 3 showing portions of the landslide area.

Once the team was back at UVM, the data was copied over to UVM servers and processing began in the following days. When the team attempted to process the LiDAR data, they received errors indicating that the data had in fact not been copied successfully in full. Because of this, the team chose to return to Smuggler's Notch on October 24, 2023, to repeat the same LiDAR flight plan. During the second visit, the team followed all the same procedures and checks as the first visit, and the LiDAR sensor battery was swapped in between flights, at the same time as the UAS batteries, and the data collection was successful. The flight trajectories completed in the two flights are presented in Figure 47.

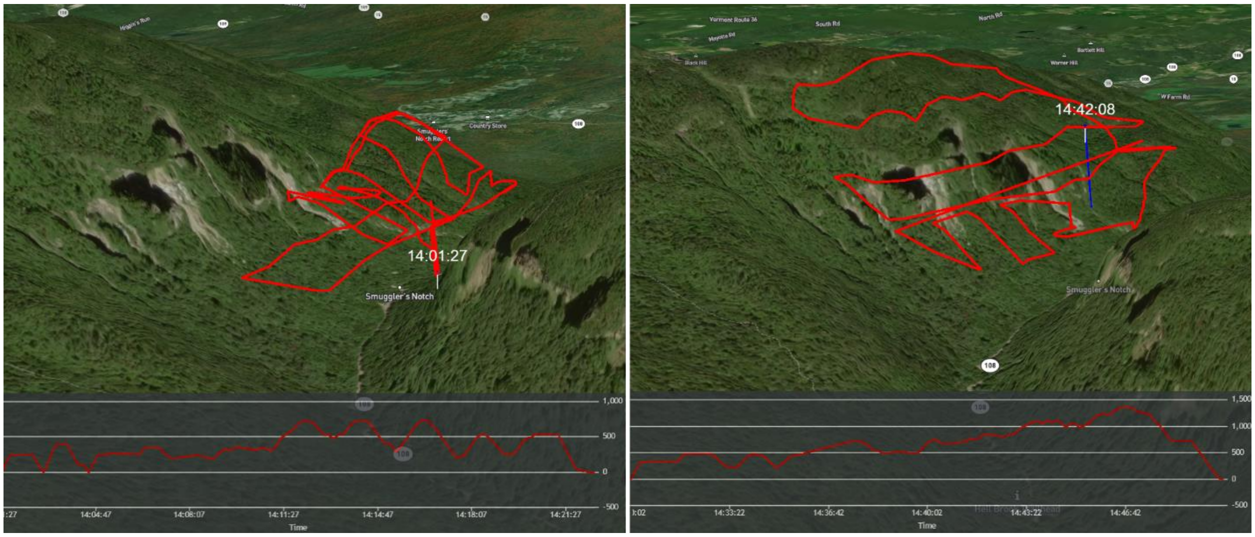



Figure 47. UAS-LiDAR collection flight trajectories 10/24/2023.

### *2.24.4 Landslide Drill Follow-Up Activities, If Applicable*

Following the completion of flight activities, the collected UAS data was processed to generate products for dissemination to geologists and other stakeholders for further analysis.

Before processing the true-color mapping data, the images needed to go through a PPK process to correct their location. Flights with the DJI Zenmuse P1 can typically be flown with RTK by connecting to Vermont's VECTOR Virtual Reference Station (VRS) network, which requires internet connection to provide real time corrections. At the flight location, LTE connection was unavailable so this service could not be used during flight. The team instead flew with RTK disabled and set up a Septentrio Altus NR2 GNSS receiver near the launch and land site to collect correction data to use as a reference for PPK processing. During post processing, it was found that the data had a low fix, which would result in a lower and less ideal accuracy. This was likely due to the mountains blocking signal to satellites, as the GeoBase was located directly within the crux of the notch. GNSS data from a CORS station in Johnson, Vermont was downloaded through VTrans VECTOR online website and utilized as a reference source to correct the positions of the collected images.

Once the locations were corrected, the imagery was processed using Pix4DMapper photogrammetry software. The images from both true-color mapping flights were processed together as a single dataset. By processing imagery collected at multiple angles together, the complex features of the landscape are better represented in the resulting orthomosaic (Figure 48). According to the processing report produced by Pix4DMapper, a total of 673 images covered over 120 acres.

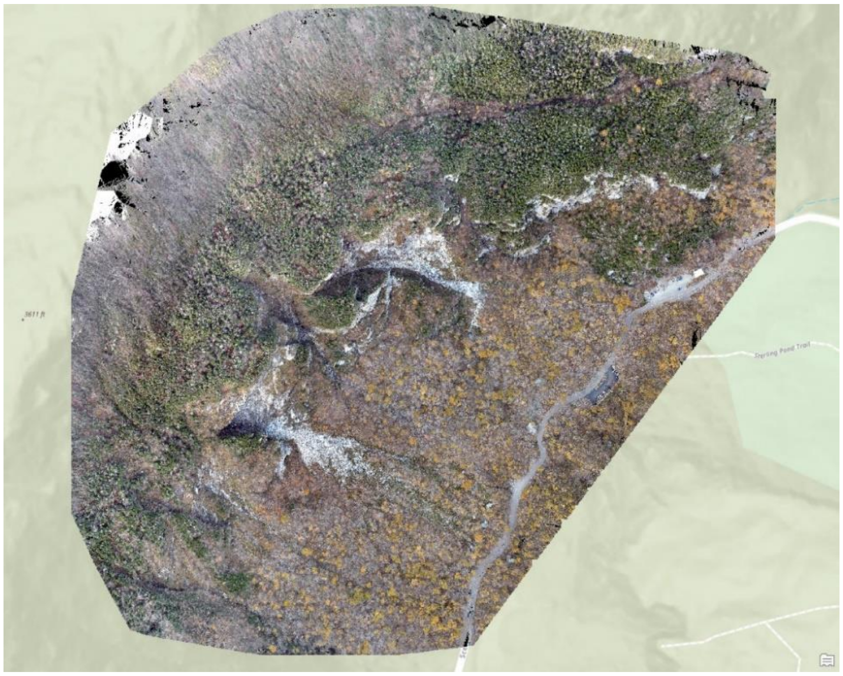


Figure 48. The true-color orthomosaic generated from processing the two UAS mapping imagery collections together.

The orthoimagery provides a high-resolution map of the area that is free of distortions and can be used for accurate and precise measurements. This orthomosaic product is much higher quality than other aerial imagery that may be outdated and lower resolution (Figure 49).


Figure 49. Comparison between satellite basemap imagery (left) and the UAS orthoimagery (right) of the Smugglers Notch landslide.

The LiDAR data processing began with PPK corrections of the sensor flight trajectory using Applanix POSPac software and the CORS station data. A point cloud was generated using YellowScan CloudStation software and the corrected trajectory. Utilizing LAStools software, the point cloud was classified to differentiate between ground and above ground features, and then used to generate a digital elevation model (DEM) representing bare earth and a digital surface model (DSM) representing the topography of all features (Figure 50). These highly accurate models of the landscape provide detailed information about the terrain and allow for in-depth analysis of the past landfalls and future hazards. Finally, the resulting point cloud was colorized in QT Modeler using the orthomosaic (Figure 51).

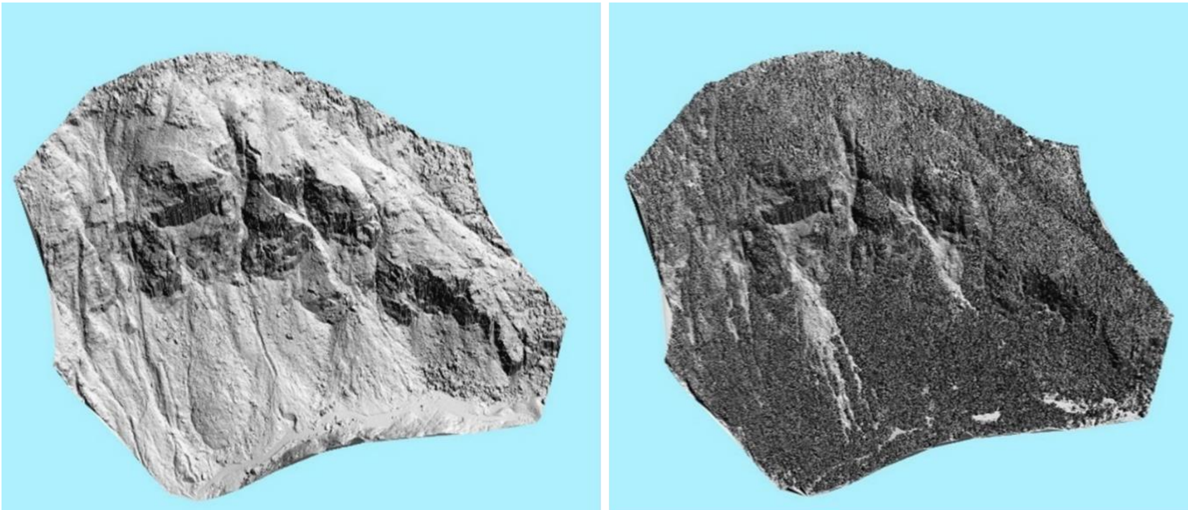


Figure 50. DEM (left) showing only bare earth, and DSM (right) showing bare earth and above-ground surfaces.


Figure 51. Colorized point cloud.

Once all data was processed, the products were integrated into ArcGIS Online for easy sharing with stakeholders. The orthomosaic and elevation layers were added to a publicly available web mapping application, which can be accessed at the following link: https://go.uvm.edu/xyigj.

The UAS data products generated from this drill, in addition to past data gathered at this location, were distributed to by UVM and state geologists, VTrans, and other stakeholders to track changes in these landslide paths over time and to identify areas that may be at risk for future slides. The identification of rockfall hazards relies on the ability of geologists to determine both the causes of rock falls and to identify areas of repeated activity. High-resolution topographic data acquired by sUAS are an efficient means of obtaining this information. During initial surveys, we found that acquiring optical imagery alone can be of limited value due to forest cover, which can obscure debris fields and boulder pathways in spring and summer. In contrast, the simultaneous collection of LiDAR and optical data provided three-dimensional (3D), photo-textured representations of the topography that aided geological analyses of the site (Figure 52). These analyses included identifying areas of recent and ancient slips and measuring the orientations of features responsible for rockslides. Among the digital products most useful for the analyses were: 1) classified point clouds, 2) DSMs, 3) DEMs, and 4) normalized digital surface models (nDSM). Similar approaches are becoming increasingly common because they enable geoscientists to perform multi-scale, repeatable analyses that are difficult, if not impossible, to achieve using conventional mapping methods (e.g., Buckley et al., 2019; Nesbit et al., 2020).

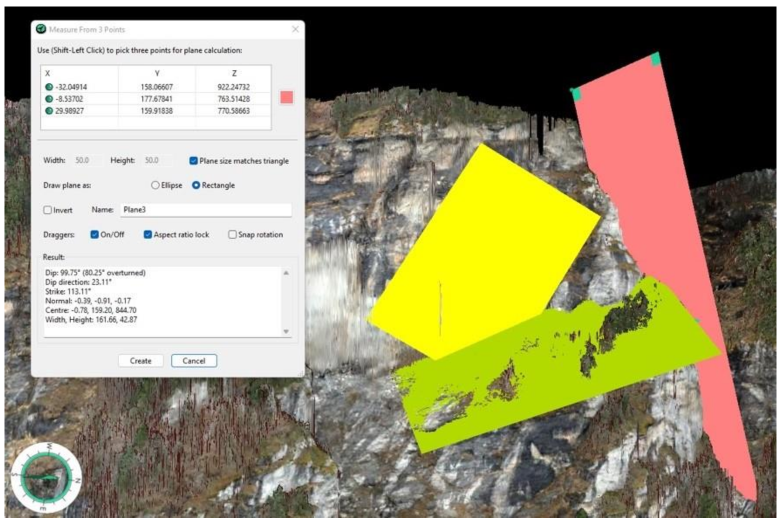



Figure 52. Oblique view of photo-textured point cloud collected using sUAS at Smugglers Notch. Image shows how the georeferenced 3D data can be used to accurately measure features that cause rock falls at the site. Three fracture sets (colored planes) intersect to form a large hazardous region (arrow) that is likely to collapse in the future. Image and geological analysis by Keith Klepeis using LIME software.

### *2.24.5 Lessons Learned from the Landslide Drill, Including Responses to Research Questions*

#### 2.24.5.1 Landslide Drill Key findings:

1. For steep cliff faces or landslides, a camera that can rotate on multiple axes is helpful in capturing mapping images of the complex terrain. When collecting images of the landslide during the mapping missions at Smuggler's Notch, the camera was set to an oblique angle as opposed to nadir, allowing for better capture of some of the steeper rock faces. For efficiency, the platform had been programmed to fly perpendicular to the landslide to minimize its ascent and descent. This required the UAS or sensor to also rotate the direction it was facing to capture images of rock faces. Having the flexibility to adjust the camera expanded and improved the flight planning capabilities for the landslide, providing the potential for more efficient and higher quality collections.
2. With complex terrain surrounding landslide sites, it can be beneficial to attempt various flight plans if time allows to guarantee good coverage. The ability for angled mapping collection

expands flight planning capabilities. While the team believed that an angled mapping mission could capture the steep rock faces better than a nadir collection, there was no guarantee in the field of what angle might work best. Therefore, two different mapping missions were flown, one of the whole area with the camera looking slightly up from nadir (at a 85° angle), and another flight looking up at the steeper portion (at a 25° angle). The second angle was chosen based on the estimation of the slant of the rock slope. Combining the images captured from both flights produced a more robust orthomosaic than the data from either flight alone. This exemplifies that there may be practices that may be outside of standard product generation workflows that can improve results for complex locations such as landslides.

3. Operating in alpine environments presents challenges for RTK GPS corrections and PPK positioning with a local base. The landslide drill occurred in an alpine environment, with flight operations taking place between steep mountains.
4. The orthomosaic produced from the mapping flights proved to be valuable for visualization of the scene, as well as colorization of the LiDAR point cloud. The orthomosaic generated of the Smugglers Notch Landslide provided a high-resolution map of the site which was free of distortion and could be used for accurate measurement making. It also had value in colorizing the point cloud that was generated from LiDAR collection, producing a more realistic looking and interpretable 3D model. In previous years, the imagery collected during mapping missions had also been used to create point clouds using SFM techniques. It was found during this October 2023 collection and processing, however, that the LiDAR point cloud had higher accuracy and captured more of the landslide than the photogrammetry method.
5. Because the landslide was in a complex alpine environment, the flight team encountered a variety of challenging weather conditions while attempting to collect data. Prior to successful collection in October, there were previous flight attempts that had to be grounded due to unexpected high winds or heavy fog traveling over the mountain. These rapidly changing weather conditions could not necessarily be predicted ahead of time, and therefore required decision making in the field to mitigate risk and safely land the UAS.
6. Utilizing a Smart AGL terrain-following feature allowed the UAS to maintain a safe distance from cliffs while being compliant with Part 107 regulations.
7. A lack of SOPs to be followed at the conclusion of every flight (i.e. copying data from the sensor USB stick or SD card after each flight and beginning each flight with new batteries in both sUAS, sensor, and accessories) can result in corrupted or missing data, which requires additional flights and time to complete.
8. LiDAR sensors capable of collecting data over 360° swaths can provide highly detailed and accurate elevation data of landslide path and vertical cliff faces to be used in geological analysis.
9. If collecting both orthoimagery and LiDAR at a landslide site, carrying out the mission profile with a higher altitude first allows for the RPIC and VOs to become more familiar with the potential limitations in operating with VLOS. Typically, orthoimagery can be captured at higher altitudes (300-400ft AGL), while some LiDAR sensors may require data collection between 200-300ft AGL.

#### 2.24.5.2 Landslide Drill Recommendations:

- For a landslide response, consider using a platform and image sensor combination that allows for gimbal movement and adjustments to the camera angle to capture better coverage of steeper rock faces and slanted surfaces. It is ideal to capture images perpendicular to the face of the landslide when practical.

- When mapping a landslide with complicated rock faces and other features that may pose challenges to processing and producing high quality results, it is beneficial to complete multiple flight plans at different angles if time allows. This will provide flexibility during processing and help determine what techniques will work best for the particular site.
- Consider ahead of time whether RTK or PPK can be used for the flight operations and have one or more backup options available in case of challenges due to complex terrain, outages, or other unforeseen circumstances that may arise during a natural disaster or other emergency. It is recommended to utilize RTK if possible, followed by PPK as a backup. PPK can be accomplished either with a local GNSS receiver and/or the use of CORS GNSS stations. However, be aware that CORS stations may not be operational during certain disasters. Having as many options as possible will provide the greatest chance for success.
- Be flexible and willing to reevaluate new launch and land locations on site, or have VOs move throughout the operations to assist with LOS. Although emergency situations do not allow for choosing the time of year to respond, being aware of the different challenges such as dense canopy cover in the summer, temperature extremes in the winter, or frequent rain in the spring, is important when mission planning. Although a certain LZ and VO location may work for one UAS and sensor, it could still be beneficial to scope other locations in case another UAS and sensor package needs to be used due to differences in takeoff methods, flight height, etc.
- Based on the terrain and environmental conditions of the landslide site, possible weather conditions and contingency plans should be discussed ahead of time so that the flight team is aware of and ready for changing conditions and knows how to safely operate the UAS or land it if needed. Be sure to review Part 107 guidelines about operating weather, as well as the manual for your platform and sensor. It can be helpful to establish clear procedures internally, as well as a checklist, so that all pilots in your organization have a standard to follow.
- Consider using Smart AGL or other tools that allow the generation of a flight plan that considers distance from terrain in all directions, not just vertical, to maintain as much distance from obstacles as possible and optimal line of sight while remaining compliant with Part 107 regulations.
- Establish and enact SOPs and/or checklists to be carried out at the conclusion of each individual flight, to ensure that the data is collected as anticipated.
- Carry out the mission profile with a higher altitude first if collecting both orthoimagery and UAS-LiDAR. Typically, orthoimagery can be captured at higher altitudes (300-400ft AGL), while some LiDAR sensors may require data collection between 200-300ft AGL.

#### 2.24.5.3 Landslide Drill Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. In a landslide scenario, a multirotor UAS is ideal for maneuvering across steep terrain. Having a UAS platform compatible with multiple sensors is a convenient way to gather multiple types of data such as imagery and LiDAR using the same UAS platform. When capturing imagery

of steep terrain, utilizing a sensor with a gimbal that allows the camera to rotate in multiple directions can improve efficiency when capturing mapping data at oblique angles.

2. For this drill, the UVM UAS Team communicated with UVM and state geologists to ensure that the data would benefit landslide monitoring and future hazard mitigation. The team also communicated with VTrans to coordinate when and where ideal staging locations would be alongside a narrow, busy road in a popular state park.
3. When operating in the steep terrain of a landslide area, there is always a risk for collision with terrain or an obstacle. To mitigate this risk, the UVM UAS Team utilized the UgCS Smart AGL tool to ensure that the UAS was as far from the terrain and any obstacles as possible while remaining in compliance with Part 107 regulations. VOs were deployed to further support the RPIC.

   Checklists were used to verify suitable weather conditions for flights in a dynamic and harsh alpine environment.

4. N/A
5. When engaging in manual flight for the purpose of scouting out a flight area, evaluating line of sight, and collecting oblique images and videos, a small multirotor works best.

   For a mapping mission, having a larger multirotor with swappable payloads allowed the team to capture both true-color imagery and LiDAR using the same UAS platform.

6. *LiDAR:* multirotor capable of medium/heavy payload lift. Minimum 20 minutes of flight time. Ability to plan and execute complex automated flight paths, considering elevation data. Ideally some methods of obstacle detection and/or avoidance.

   *Orthoimagery:* multirotor capable of carrying EO camera on gimbal. Minimum 20 minutes of flight time. Ability to plan and execute complex automated flight paths, considering elevation data. Ideally some methods of obstacle detection and/or avoidance.

7. N/A
8. N/A
9. N/A
10. This drill identified the necessity of changing the batteries of both the UAS and sensor in between each flight, and this should be incorporated into standard practice between each individual flight. In this case, UVM was able to return to the site a few days later to repeat the LiDAR flight and ensure that data was successfully collected, but in a more time-sensitive response and oversight like this could have cost the team a valuable dataset.
11. For a landslide response, UAS allowed data capture of a small area and gathered much higher detail than manned aircraft could have, since UAS were able to fly at a lower elevation and gather imagery from a variety of angles.

    Manned aircraft would be unlikely to capture actionable data at the resolutions required of such complicated and steep terrain.

#### 2.24.5.4 Landslide Drill Lessons Learned Summary:

UAS flights to collect LiDAR and orthoimagery provides tremendous value in supporting multiple aspects of landslide response and resiliency. However, flight operations in steep and complex terrain can pose significant risks that must be mitigated by careful flight planning and the use of risk mitigation techniques.

There are two levels of risk associated with landslides, immediate (which includes imminent risk) and long-term. For an assessment of imminent risk in the hours and days following a slip event, the rapid deployment of sUAS proved essential because it provided information that cannot be obtained by other means. This information included identifying potential evacuation routes and locating areas of instability relative to infrastructure (roads, parking areas, facilities) and recreational areas (hiking trails, rock climbing sites).

An assessment of long-term risk relies on the ability of scientists to make predictions about future rock falls. To achieve this, repeat surveys in the months and years following rock fall events in 2020 were especially useful. Repeat surveys can inform geologists to determine where and how the landscape is changing over time. This information is needed for constructing hazard maps and for making predictions about where future rocks falls may occur and maps that show the probability of rock falls in the future

## 2.25 2/01/2024, Seminar, Train Derailment, Burlington, VT and Online, Conducted by UVM

The second seminar in preparation for the train derailment exercise was a hybrid meeting. Due to the Great Vermont Flood of July 2023, the timeline for the train derailment exercise was adjusted to allow UAS Teams and first responders in the state to focus on flood response in 2023. This seminar would serve as a reintroduction to the event, with the goal to host the exercise in the spring of 2024. This was the first meeting related to the planned exercise that occurred after the passing of the SAL's Director in January 2024.

### *2.25.1 Objectives of the Train Derailment Seminar*

The objective of this seminar was to refocus attention on the train derailment mock exercise, refamiliarize participants with the roles and responsibilities, and redefine the timeline for the remaining seminars and actual exercise.

### *2.25.2 Planning for and Logistics of the Train Derailment Seminar*

This train derailment seminar was planned by UVM to return focus on the exercise; a date was finalized, and a Microsoft Teams invite sent out for those who needed to attend virtually. Discussion topics were noted prior to the start of the meeting to consider as a group, which were based on previous seminar discussion and remaining questions.

### *2.25.3 Train Derailment Seminar Execution*

UVM presented information via PowerPoint including a reminder of the exercise objectives, previous workshops and seminars, and the remaining logistics to work out. Throughout the presentation, open discussion was held amongst participants to provide input, questions, concerns, suggestions, ideas, and other valuable insights. Following the presentation, conversations expanded on these topics and any other relevant considerations. Several key decisions were finalized including:

- UVM, VTrans, and USAR VT-TF1 confirmed their ability to carry out flight operations. Due to the lapse in time from the previous planning meetings, this was key in ensuring the exercise could move forward with the planned flight operations.
- Burlington Parks, who manages the desired exercise location, confirmed permission to set up on the chosen site and safely access the roadway, allowing for vehicles and UAS equipment transportation
- The airspace would be designated ahead of time using Google Earth Pro to provide the Air Boss with defined areas for each flight team; an example is shown in Figure 53.

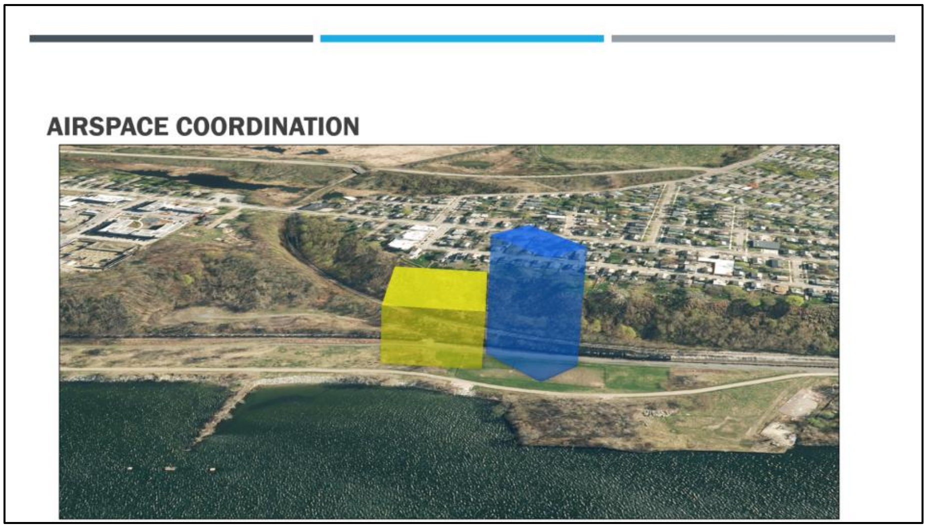



Figure 53. Example of airspace partitioning by using colored blocks in Google Earth Pro.

- A final date was set for the event of April 2, 2024, with a backup date for inclement weather or other setbacks being the following day of April 3.
- It was decided that the UAS Air Boss simulates the start of the exercise the morning of April 2, with an email to all responders sharing a request for UAS support. The email simulation was designed to be good practice for a real-world emergency as it replicates how a UAS support request might come through the channels for those who are not directly integrated in the EOC, or in case the EOC is not activated.

#### *2.25.4 Train Derailment Seminar Follow-Up Activities, If Applicable*

The main follow-up activities were for UVM to schedule the next seminar, finalize an updated timeline for the event, and continue to establish the logistics for the mock exercise. These details were developed into an exercise plan for participants as well as a test plan which was submitted to the FAA. Plans were to include information such as objectives, flight location, exercise scenarios, mission profiles, participants and roles, scheduling, data management, and more. This was a convenient way to consolidate all of the plans made throughout the seminars, add a robust number of details and figures, and present the information in a digestible manner.

### *2.25.5 Lessons Learned from the Train Derailment Seminar, Including Responses to Research Questions*

#### 2.25.5.1 Train Derailment Seminar Key findings:

1. Google Earth is an accessible application that many people are familiar with, which has the capability to designate areas for visualization of airspace partitioning.
2. During a live event, and especially a natural disaster, there may be inclement weather which grounds UAS flights and impedes the collection of data. This may or may not be the case during the exercise, but it is crucial to be aware of and consider all possibilities and contingency plans.
3. For UAS groups not receiving direct tasking from the EOC/ICS, there may be pathways for their support to be requested through another agency.

#### 2.25.5.2 Train Derailment Seminar Recommendations:

- Improve and refine methods for the use of Google Earth or related applications to delineate and visualize sUAS airspace portioning and management.
- Develop clear protocols for when to ground operations for inclement weather or other challenges and have contingency plans for data collection.
- UAS groups that are not receiving direct tasking from the EOC/ICS could reach out and establish relationships with those groups or agencies that are a part of the structure, allowing for indirect tasking and support.

#### 2.25.5.3 Train Derailment Seminar Informed Research Question(s):

1. N/A
2. It was determined that the UAS Program Manager at VTrans would send out the tasking and request UVM and USAR VT-TF1 for support, simulating what a real-world event might entail. This emulates the potential for coordination between agencies such as VTrans that are integrated into the EOC, to task other UAS groups that are not directly functioning in that structure.
3. Inclement weather is a common risk for this use case, as there is no guarantee that weather will be within operating limitations during the response. High wind, heavy rain, low cloud ceiling, or other environmental conditions could increase risk during operations and require UAS to ground operations. Mitigation for this could include
   - Be aware of operating limitations set by the manufacture, such as max wind speed or resistance to precipitation.
   - Checking the conditions using multiple different resources before deployment to be aware of and prepared for any inclement weather.
   - Having an application available during operations and designating a person to check for changing or worsening conditions.
   - Consider bringing a wind meter or other devices to verify conditions.
   - Be proactive and alert in check wind speed or other notifications available during UAS flight.

   Risk of collision with multiple UAS teams operating in the same airspace

   - Google Earth could be used to generate a visualization of partitioned air space, with designated zones, altitudes, buffers, etc. Briefing pilots with this information ahead of time and offering the usage of KMLs for geoboundaries will aid in avoiding overlap in UAS flights.

4. N/A
5. N/A
6. N/A
7. N/A
8. N/A
9. N/A
10. While operating limitations from manufacturers can be helpful, they are often vague and do not provide enough detailed information to know at what point it is no longer safe to fly UAS. For example, max wind speed is a common number provided by manufacturers and many UAS can detect and relay this during flight, but levels of precipitation are not as clearly defined and can greatly vary per platform. Further testing of these technical standards could result in safer operations.
11. N/A

#### 2.25.5.4 Train Derailment Seminar Lessons Learned Summary:

Within a locality or region, there could be the possibility for forming relationships between agencies to ensure collaborative tasking of UAS support following a disaster. For response efforts with multiple UAS operations occurring simultaneously, dividing and visualizing the airspace allocated to each mission profile (using an application such as Google Earth) can aid in UAS teams' coordination efforts. During operations, UAS teams should also be aware of the possibility of inclement weather and understand the limitations and procedures for safe flight or emergency landing if required

## 2.26 3/12/2024, Workshop, Train Derailment, Burlington, VT and Online, Conducted by UVM

This train derailment workshop was a hybrid in-person and virtual meeting. With less than a month until the exercise date, the meeting served to review plans, discuss final equipment and preparation tasks, and confirm that permissions and support are in place. The attendees included UVM Spatial Analysis Lab, UVM Emergency Management, VTrans, and USAR VT-TF1.

### *2.26.1 Objectives of the Train Derailment Workshop*

The objective of this workshop was to ensure all UAS teams were aware of their roles, responsibilities, and remaining preparation tasks leading up to the exercise. A secondary objective was to identify methods for capturing lessons learned during the event.

### *2.26.2 Planning for and Logistics of the Train Derailment Workshop*

This train derailment workshop was planned at the conclusion of the previous seminar, with UVM finalizing a date and sending out a Microsoft Teams invite for those who wished to meet virtually and booking a room for those meeting in-person. Ahead of the meeting, UVM developed a comprehensive exercise/test plan including key details to share with those involved. This meeting provided an opportunity to review the exercise plan thus far and gather feedback through discussion.

### 2.26.3 Train Derailment Workshop Execution

A conversation was held amongst attendees to continue working out the details of the exercise event leading up to the final seminar. At this stage in the planning process, it was crucial to consider the small details and logistics to ensure the exercise and operations went smoothly. UVM did not present a PowerPoint, but instead guided discussion. The following tasks were executed leading up to or during the seminar:

- Determined number of pilots and visual observers for each team. Most teams would consist of one person acting as a pilot, and one or more acting as a VO, with the ability to switch roles. This way, both roles could be practiced and the pilot would not feel fatigued.
- Updated site map to include a buffer around the railroad, which would ensure safe movement around the site.
- Generated a list of necessary equipment. Examples include launch pads, cones, hand-held radios, high-viz vests, and related items for safe operations. Each team developed their own list of equipment based on their own needs and preferences, and equipment was shared if needed. This was a helpful task to brainstorm what technology and gear might be necessary in a real-world deployment.
- Discussed and decided on the approval process for airspace authorization through LAANC, which would be submitted by each flight team in the field before operations and confirmed by the UAS Air Boss before take-off.
- Decided that an Assistant Air Boss will monitor the airband radio and help with other tasks so that the Air Boss can focus on communication with the flight teams.
- Designated that the Air boss will determine call signs and radio communication techniques.
    - Teams would be color coordinated to align with visual map of airspace partitioning.
- Created a safety officer role which would be filled by UVM Emergency Management, who would give a safety briefing, serve as a resource, and be available in case of an emergency or other incident.
- Confirmed that data products will be processed by UVM and delivered to VCGI, a step that would replicate a real-world emergency scenario. This workflow was informed by UVM's UAS response to the flooding in 2023, where sharing UAS products to the cloud with the help of VCGI was a crucial step in getting data out to those who needed it.
- Finalized anticipated roster, which was to include over 40 participants or observers.

### 2.26.4 Train Derailment Workshop Follow-Up Activities, If Applicable

The follow-up activities for UVM included scheduling the next and final workshop, as well as conducting a site visit to better visualize the space and validate plans. Another major task was to complete the test plan and generate KML files of the airspace, muster locations, and other important features to send out to participants.

### 2.26.5 Lessons Learned from the Train Derailment Seminar, Including Responses to Research Questions

#### 2.26.5.1 Train Derailment Seminar Key findings:

1. Depending on the specific event, platform and sensor availability, and other shifting parameters, UAS team sizes often fluctuate with number of pilots and visual observers and there may be a different solution for varying groups.

2. When responding to emergencies, it is crucial to ensure operators and personnel are not interfering with the safety or impeding other aspects of the emergency response, as this can be possible at an active scene.
3. Considerations and preparation should be directed towards supporting equipment required for UAS deployment such as PPE, signage, power banks, WiFi connectivity devices, toolkits, and more.
4. It is crucial to ensure UAS teams have airspace authorization before beginning flights, which could be verbally confirmed by a UAS Air Boss or might benefit from some type of digital tracking and record keeping. Each team is responsible for ensuring that they will be conducting operations within the bounds of the regulatory environment.
5. Effective application of a UAS Air Boss requires standardized communication. Air Boss serves as 'hub' in hub-and-spoke model of communication for individual flight teams.
6. With a large or complex operation, it could be useful to have an Assistant Air Boss to help with airspace monitoring, flight tracking, and other tasks that are not yet entirely known or defined.
7. Following UAS data collection, sharing the products through online, cloud-based services such as ArcGIS Online will speed up sending files and provide an accessible format for a range of stakeholders and end users.

**2.26.5.2 Train Derailment Seminar Recommendations:**

- UAS teams should reflect on past exercises and operations to determine the appropriate number of pilots, visual observers, or other crew members while taking into consideration the length and complexity of the response. For example, determining whether multiple pilots are needed to switch roles, or if more than one visual observer is needed.
- To avoid interfering with the safety or impeding other aspects of the emergency response, the lead of UAS operations should let others on site know of the flights, launch and land from a space that is not in the way, and verify that flights will not impact movement of other key people, vehicles, equipment, or related needs.
- Each UAS team should develop checklists for gear and equipment specific to their operations, which can be referenced before deployment to speed up the process and avoid leaving valuable items behind. These lists could be informed by exercises and drills as well as past experiences and future needs.
- Research and determine a preferred method for verifying airspace authorization has been received before flight, especially if there are multiple UAS operations from various agencies.
- Based on the expected role of a UAS Air Boss during operations, determine if an assistant would be useful and if so, define what tasks would be beneficial and what type of experience would be necessary to choose a qualified person.
- Refine workflows to efficiently process, upload, and share UAS products to cloud services and other digestible formats such as ArcGIS Online tile services.

**2.26.5.3 Train Derailment Seminar Informed Research Question(s):**

The research questions outlined in Section 1.1 were informed by this event as follows:

1. N/A

2. It was decided that each of the separate UAS teams would submit their own LAANC airspace request to ensure their operations were approved, and then would need to verify this approval with the Air Boss before beginning flight operations. This interagency, redundancy, and communication promotes best practices regarding airspace approval and strengthens collaboration between pilots of different organizations and a singular Air Boss.
3. N/A
4. N/A
5. N/A
6. Disaster sites often have people, cars, equipment, debris, and other obstacles that may make it challenging to find space for safe UAS launching and landing, making multirotor an ideal platform when there is no guarantee for wide open space to launch a fixed-wing UAS.

   During an emergency response, there are often time sensitive missions or limited access to an area for safety concerns, making UAS with relatively easy set-up and quick deployment ideal.
7. N/A
8. N/A
9. N/A
10. As with the need for a UAS Air Boss position, there are many instances during more complex operations where an Assistant Air Boss could be valuable as well. Development of this role and associated qualifications for a more standardized position would be helpful for UAS operations, especially when collaborating with external partners.

    Besides the UAS Air Boss and Assistant Air Boss roles, there could be a benefit for refining guidelines for team makeup, such as how many certified pilots are recommended for long or intense emergency response operations. Additionally, an approved VO training course would be beneficial for those who may be involved in acting as a VO but do not have their remote pilot license

    Without a designated ICS structure, it is difficult to understand how UAS operations may fit into ongoing emergency response. Procedures and guidelines for this coordination between ground and aerial efforts amongst agencies would be useful to improve collaboration, efficiency, and safety of UAS in a disaster.
11. N/A

#### 2.26.5.4 Train Derailment Workshop Lessons Learned Summary:

Although UAS team dynamics fluctuate depending on the scenario, there could be benefit in guidance and standardization surrounding number of pilots and visual observers required for a safe response to a disaster, as well as the qualification and experience level for a UAS Air Boss and Assistant Air Boss and even VOs. When a UAS team arrives on scene, there can also be uncertainty surrounding their role within the rest of the ground response, so it is crucial to ensure UAS operations are not impeding other tasks of higher priority through integration with ICS. Effective emergency response operations require preparation beforehand including checklists for equipment and gear, development of standardized communication, proper airspace approval, and understanding of data processing and sharing needs for the end user.

## 2.27 3/28/2024, Workshop, Train Derailment, Burlington, VT and Online, Conducted by UVM

The final workshop was a hybrid in-person and virtual meeting. This meeting served to present final plans to participants and attendees, confirm roles and responsibilities, and prepare for the exercise the following week. The attendees included participants from UVM Spatial Analysis Lab; UVM Emergency Management; VTrans; Vermont Urban Search & Rescue Task Force 1; UAH; KSU; VCGI; Center for Naval Analysis; Burlington Parks, Recreation, and Waterfront; Vermont Rail Systems; and Burlington Fire Department.

### *2.27.1 Objectives of the Train Derailment Workshop*

The objective of this final seminar was to review the exercise plan with flight teams, participants, observers, and other stakeholders to allow space for review and questions, if necessary, before the exercise the following week.

### *2.27.2 Planning for and Logistics of the Train Derailment Workshop*

This final train derailment workshop was planned by UVM after the previous workshop; a date was finalized and an online invite sent out for those who needed to attend virtually. UVM conducted a site visit of the planned exercise location, finalized exercise plan documents with detailed information about the event, and generated additional maps, graphics, and schedules for the participants.

### *2.27.3 Train Derailment Workshop Execution*

UVM presented information via PowerPoint, guiding attendees through the plan and highlighting specific roles and responsibilities. Throughout the presentation, open discussion was held amongst participants to ask questions or provide suggestions. Following the presentation, conversations expanded on these topics and any other relevant considerations, with the goal in mind of being ready for the exercise the following week. A variety of topics were discussed to finalize the mock exercise preparations, including, but not limited to:

- A review of the vision, mock scenario, and objectives for the exercise so that all participants are aware of the goal and larger context for the mock train derailment
- Assignment of participants and their roles:
    - Three organizations were categorized as UAS Operators and should be prepared to conduct flight operations (Figure 54).
    - Remaining participants were categorized as supporting roles and would not be responsible for operating UAS but providing other participatory or observatory roles. (Figure 55).
    - Besides these overviews, more specific roles for everyone, such as the pilots within each flight team, were identified.

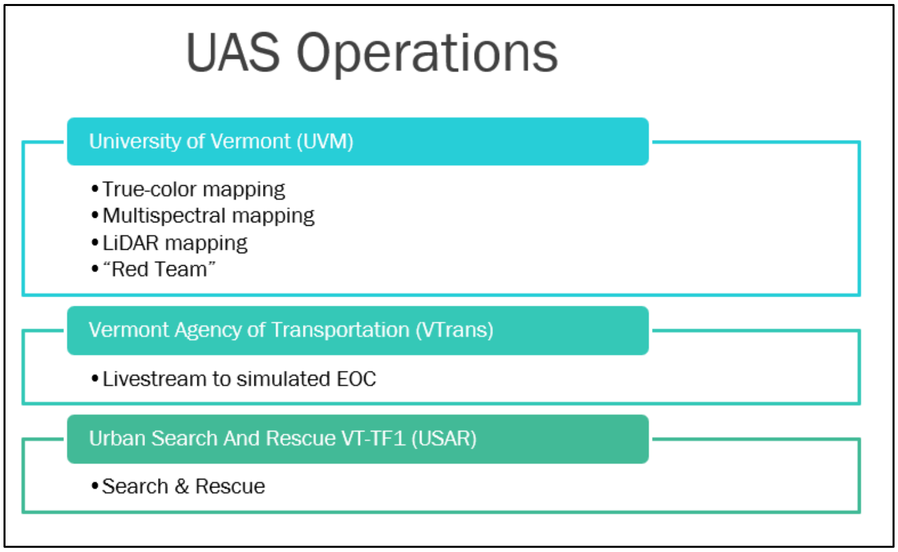



Figure 54. UAS Operations for each of the three participating groups.

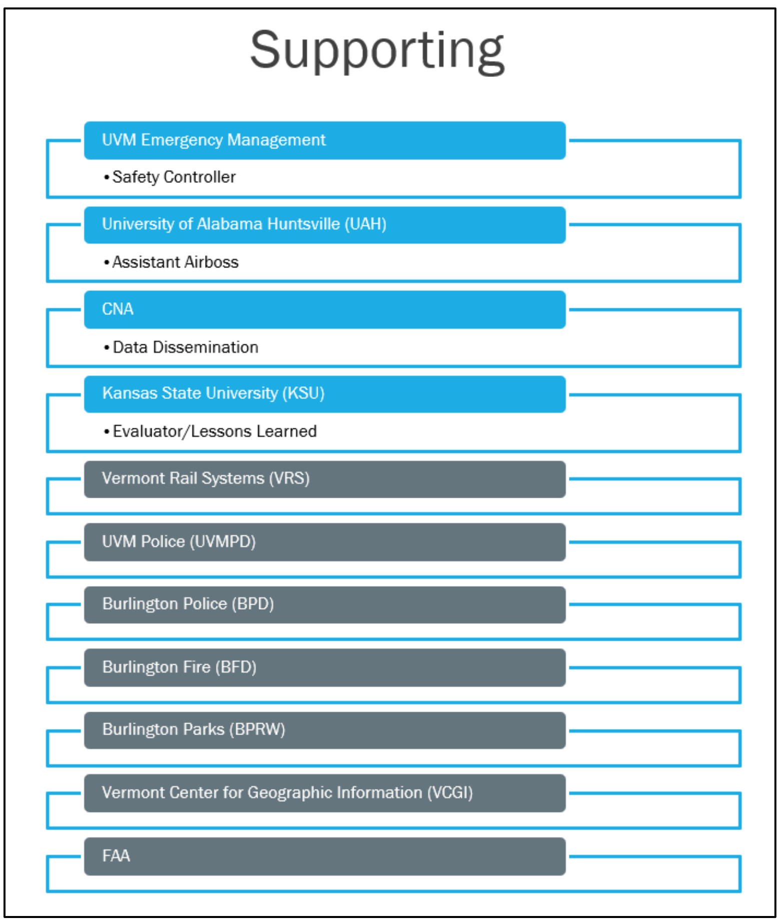



Figure 55. Organizations and agencies that will be providing supporting roles during the mock exercise.

- The flow of the exercise, which includes a request for UAS assistance, approval of operations in the airspace, mobilization of teams, execution of data collection, and dissemination and analysis of the UAS products (Figure 56).

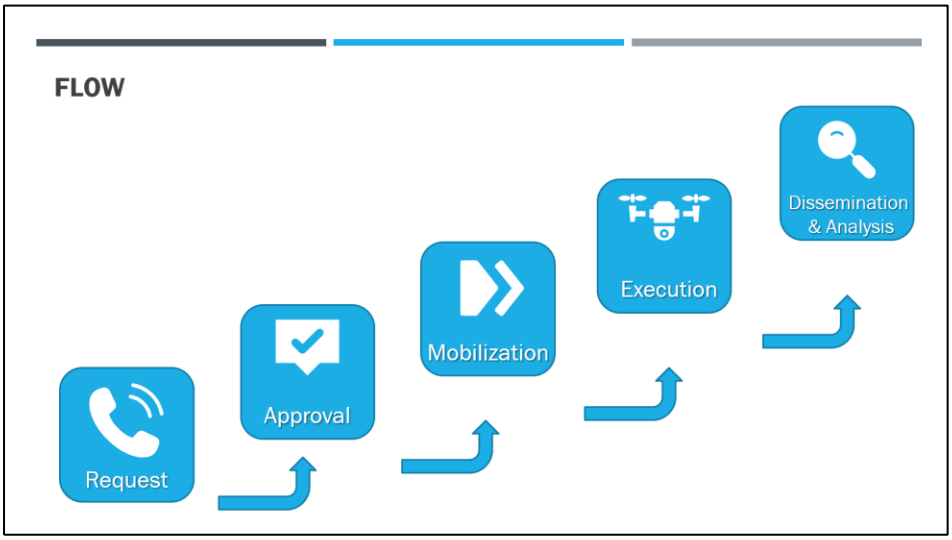



Figure 56. Flow of the mock exercise from the initial request to the data dissemination and analysis.

- A detailed look at the location (igure 57). There would be a defined operational area, buffer around the railroad, and designated launch and land zones which could be altered upon arrival and setup as needed.


Figure 57. Exercise location with the orange representing operational area, blue representing a buffer around the rail line for attendees to avoid, and a red point for the proposed launch/landing zone.

- The execution of the exercise would include a safety briefing beforehand to discuss safety and risk mitigation, the start of the exercise and briefing from the Air Boss to confirm communication and coordination efforts, flight operations from multiple groups, then the end of the exercise and a hot wash to debrief (Figure 58).


Figure 58. Steps for the execution of the exercise from the initial safety briefing to the hot wash.

- Risks and safety considerations
    - Telephone poles, trees, and other obstacles
    - Railroad tracks
    - Changing terrain and environmental conditions, such as rain or wind
    - Non-participants who may enter the flight area
    - Potential for a real-world emergency during the mock exercise
- Airspace coordination and communication efforts, including the need for airspace approval, buffer around operating zones, and effective techniques to track airspace and deconflict if needed (Figure 59). Some techniques include designating different altitudes with a 50ft buffer in between, ensuring launch and land areas are clear, and consistent radio communication to confirm where each team is located.

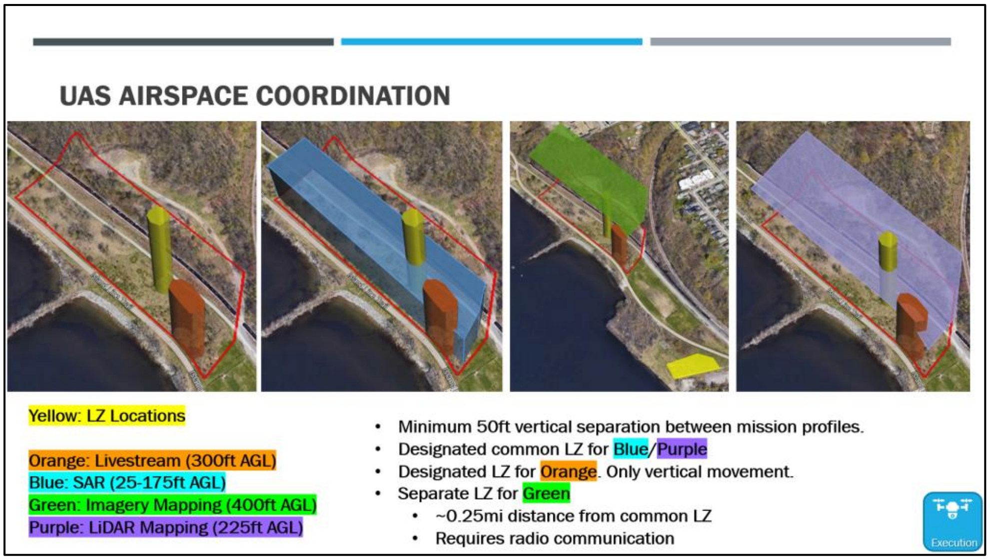



Figure 59. Coordination of UAS airspace, visualized by color-coordinated zones on a map for each flight team.

- Additional communication protocols outlined specific phrases and call signs to be used by the Air Boss when communicating with teams (Figure 60).
  - Each team would have a designated color that is used in radio communications.
  - There would be clear phrases to indicate the start, pause, resume, and end of an exercise.
  - There would be a request and approval process through the Air Boss for takeoff, landing, or resuming missions as needed.
  - Flight teams should be available to provide updates, altitude info, and other critical information to the Air Boss when requested.

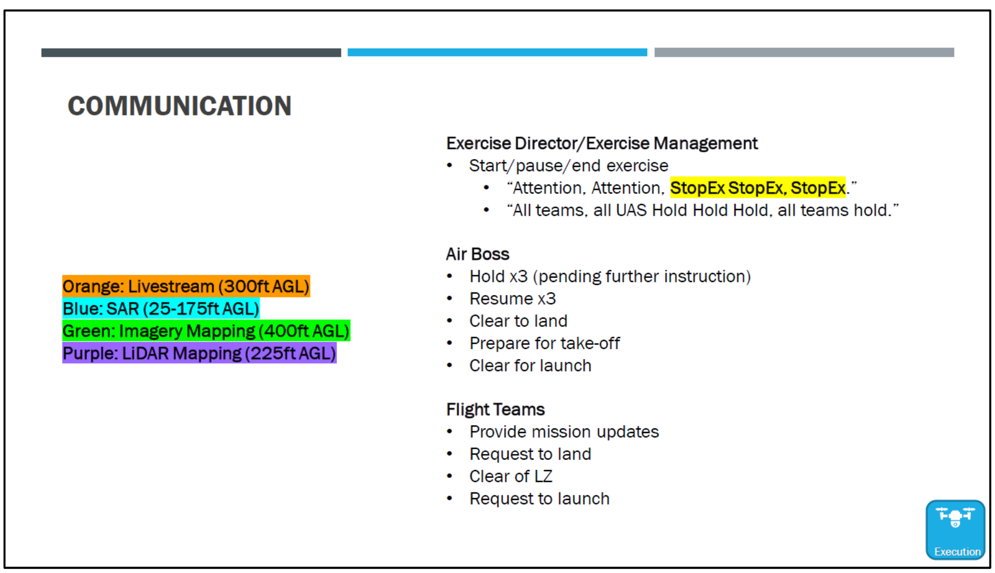



Figure 60. Standardized communication protocols for functional exercise.

- There would be two scenarios within the exercise, with the latter having an increased number of UAS operating at the same time to test out airspace deconfliction and efficient communication between teams and the Air Boss.
- Dissemination and analysis
    - The UAS livestream would be shared via a Microsoft Teams meeting and invitational link.
    - Oblique image sharing would be tested though an automated ArcGIS Online system, which is the Flight Events Tool developed through A62.
    - Remaining mapping data would be processed by UVM and shared through an ArcGIS Online Web Application. This would include true-color orthomosaic, multispectral orthomosaic, LiDAR elevation data, and historical reference data.
- A detailed schedule provided planned timing for the mobilization, exercise components, lunch, clean up, and other activities throughout the mock exercise.
- Weather and contingencies were discussed in case flight operations were not possible on the original date.

### *2.27.4 Train Derailment Workshop Follow-Up Activities, If Applicable*

After the final train derailment workshop, UVM's follow-up activities included:

- Finalizing schedule for day of exercise, including making determination of weather go/no-go for primary date and informing all participants and observers.
- Disseminating KML file containing the area of interest, potential launch and land areas, VO locations, and other key information for coordinating flights to UAS Air Boss.
- Creating preliminary flight plans for UVM's mapping operations.
- Charging batteries and preparing all equipment to be used during the exercise.
- Requesting other participants who would be conducting flight operations would also need to charge and prepare their UAS and associated equipment in anticipation of the exercise.
- Supporting VTrans UAS Program Manager (UAS Air Boss) in developing exercise StartEx email messaging.

### *2.27.5 Lessons Learned from the Train Derailment Workshop, Including Responses to Research Questions*

#### 2.27.5.1 Train Derailment Workshop Key findings:

- For a real-life emergency response, it can be challenging to predict ahead of time what the scene may look like, what risks exist, or other considerations.
- With multiple UAS operations, it is key that all pilots, observers, and crew members understand the mission profiles, intended air space partitioning, and other coordination between teams.
- It was determined that a vertical buffer between UAS operating in the same airspace would be necessary to minimize interference. A value in the range of 50ft of vertical separation was proposed as an initial baseline for testing.
- During an emergency scenario with multiple groups operating, call signs or other designated phrases could aid communication, but there can be challenges if these are not already commonly understood amongst personnel.

- UAS livestream software solutions must be compatible with sUAS equipment, but also may require compatibility with an organization's IT policies and infrastructure. Microsoft Teams was the simplest way for VTrans UAS Team to provide livestream from UAS to external and internal observers.
- There is a need for rapid orthoimagery processing and data dissemination to begin immediately after completed flights while in the field, if possible.

#### 2.27.5.2 Train Derailment Workshop Recommendations:

- When possible, scope out the response site ahead of time using easily accessible mapping applications to become familiar with potential hazards and risks, potential launch zones, and other crucial information. Prepare to adjust previously developed plans once on site; flexibility and contingency planning is key.
- With multiple UAS operations occurring simultaneously, a briefing beforehand could be a useful way to ensure all participants are aware of the airspace coordination, communication techniques, safety considerations, and other vital steps to promote clarity and safe operations.
- Carry out exercises with a variety of platforms to determine safe vertical and horizontal buffers between UAS in the same airspace, and any related limitations or challenges that may arise.
- Develop best practices for using call signs or lingo amongst a UAS team and determine how this may fit into the established communication techniques of external groups, including within ICS. Ensure there is a balance between efficiency and clarity in communication methods.
- Investigate and prepare livestream software solutions that are compatible with an organization's sUAS equipment and IT policies.
- Continue investigating the efficiency of processing orthomosaics on a laptop in the field and sharing photos and maps to online services as soon as possible.

#### 2.27.5.3 Train Derailment Workshop Informed Research Question(s):

The research questions outlined in Section 1.1 were informed by this event as follows:

1. N/A
2. For the final train derailment workshop, several groups from varying jurisdictions joined to review their roles as either an active participants, observer, or other support role, including:
    - Director of UVM Spatial Analysis Lab
    - UVM Spatial Analysis Lab UAS Team, participating in flight operations
    - Members of UVM Emergency Management, serving as safety officer
    - Members of VTrans, participating in flight operations and serving as UAS Air Boss
    - Members of Vermont USAR Task Force 1, participating in flight operations
    - Casey Calamaio - Research Engineer at University of Alabama Huntsville, serving as Assistant Air Boss
    - Kurt Carraway - UAS Program Department Head at KSU, providing evaluation and lessons learned
    - VCGI, providing data support
    - Center for Naval Analysis, providing data support

- Burlington Parks, Recreation, and Waterfront
- Vermont Rail Systems
- Burlington Fire Department

   Standardization of communication protocols between UAS Air Boss and UAS Flight Teams was developed. Examples developed for the functional exercise during this workshop include:

- Air Boss
    - Hold x3 (pending further instruction)
    - Resume x3
    - Clear to land
    - Prepare for take-off
    - Clear for launch
- Flight Teams
    - Provide mission updates
    - Request to land
    - Clear of LZ
    - Request to launch

3. Results were similar as discussed in previous train derailment seminars and workshops.
4. N/A
5. The following vehicle categories:
    - Real-time RGB livestream: multirotor with EO sensor
    - Real-time RGB/thermal search: multirotor with EO/IR sensor
    - Multispectral mapping: multirotor, fixed-wing, or VTOL with multispectral sensor
    - RGB mapping: multirotor, fixed-wing, or VTOL with EO imagery sensor
    - LiDAR mapping: multirotor or VTOL with UAS-LiDAR sensor
6. N/A
7. N/A
8. N/A
9. N/A
10. Livestream software solutions should be utilized that are compatible with an organization's sUAS equipment and IT policies.

    UAS operators involved in multi-organization operations should be familiar with LAANC approvals if operations occur within controlled airspace, and prepare to receive airspace authorizations for their mission profile.

11. N/A

**2.27.5.4 Train Derailment Workshop Lessons Learned Summary:**

The final workshop before the functional train derailment exercise provided an opportunity to review and discuss the particularly detailed aspects of the response scenario. Mission profiles for the exercise, including anticipated altitudes of each profile, were finalized and reviewed cohesively to ensure that airspace coordination would be successful. Standardized communication protocols provide consistency between flight teams and UAS Air Boss to ensure airspace coordination can be carried out safely

## 2.28 4/2/2024, Functional Exercise, Train Derailment, Burlington, VT, Conducted by UVM

This functional exercise focused on the application of UAS to respond to a mock train derailment near Burlington, VT in April 2024. The exercise was organized by the UVM UAS Team and involved multiple organizations and agencies from across the state. Both multirotor and fixed wing UAS were deployed for data collection and piloted by teams from the various agencies involved.

### *2.28.1 Objectives of the Train Derailment Functional Exercise*

The purpose of this functional exercise was to explore the potential of UAS as an effective response tool in a mock train derailment scenario:

*"VTrans has been notified that a freight train has derailed along the Burlington Vermont Waterfront near the Island Bike Trail. Information is limited as to the extent of damage to infrastructure, active fire, injuries of those directly or indirectly involved, missing persons, or hazardous materials or liquid leaking from the carts into the local environment. VTrans requests UAS support from local and state agency first responders and additional groups with UAS capabilities. Following local and federal regulations pertaining to UAS operations in controlled airspace, the Air Boss must organize, manage, and deploy multiple UAS assets to obtain unknown information, later to be dispersed to impacted stakeholders and investigating authorities."*

The primary exercise objectives were:

1. Establish coordination and communication between agencies under the direction of the Air Boss necessary for an effective UAS response, including tasking, addressing communication challenges, and airspace partitioning.
2. Ensure that UAS provides real-time support for emergency response efforts such as SAR, increased SA, and monitoring any resulting hazards.
3. Disseminate UAS data, including imagery and 3D models to enhance decision making, inspection, and future planning and mitigation efforts.

### *2.28.2 Planning for and Logistics of the Train Derailment Functional Exercise*

Planning and preparation for this event involved engaging with stakeholders throughout the state, identifying objectives that would help determine knowledge gaps, and collaborating with involved stakeholders to determine detailed plans and logistics of a realistic train derailment scenario. Multiple seminars and workshops were held to have these discussions and determine exercise logistics. Disaster scenario, location and timing of the exercise were key logistics that needed to be determined early in the planning process. A train derailment scenario was selected for its relevancy to the New England region and given that a response to an event of that scale would likely involve a multi-agency response. The UVM UAS Team responded to a train derailment in Vermont in 2015, which provided relevant experience for the team to pull from during the planning process. The Burlington waterfront was selected for the exercise location due to the presence of railroad tracks, the proximity to a densely populated urban environment and an airport, as well as other potential hazards like pedestrian traffic. Time of year was a consideration to avoid snow and extremely cold temperatures.

Next, exercise details such as participants and roles, UAS mission profiles, equipment, flight location, airspace considerations, scheduling, data management, and a communication plan were discussed with collaborators at the seminars and workshops leading up to the event. The UVM UAS Team, Vermont Agency of Transportation (VTrans), and USAR Vermont Task Force 1 (USAR VT-TF1) supplied personnel that served as RPICs and Mission Commanders (MCs) to operate the UAS and ensure that flights adhered to their organization's standards and policies. The UAS Air Boss role, filled by the VTrans UAS Program Manager, oversaw and coordinated operations and communication. The role of Flight Test Director was the primary person leading the exercise execution and was filled by the UVM UAS Team Lead. Two collaborators from KSU and UAH assumed roles as Exercise Evaluators. Each team provided at least one VO. The UVM UAS Team provided additional VOs for increased SA during flight operations, in addition to having personnel on site to interface with members of the public and inform them about the purpose of the exercise. Each organization was responsible for managing their collected data. The VCGI, whom the UVM UAS Team has a working relationship with, helped supply data visualization capabilities for UAS data collected during the exercise. Processed data was shared with VCGI and compiled into a web mapping application for dissemination with the goal to replicate a sharing workflow seen in a real-world response scenario.

During the planning process, flight teams were divided up by organization and assigned UAS mission profiles according to each group's capabilities and expertise. UAS mission profiles were selected to reflect what could be used in a real-life train derailment event:

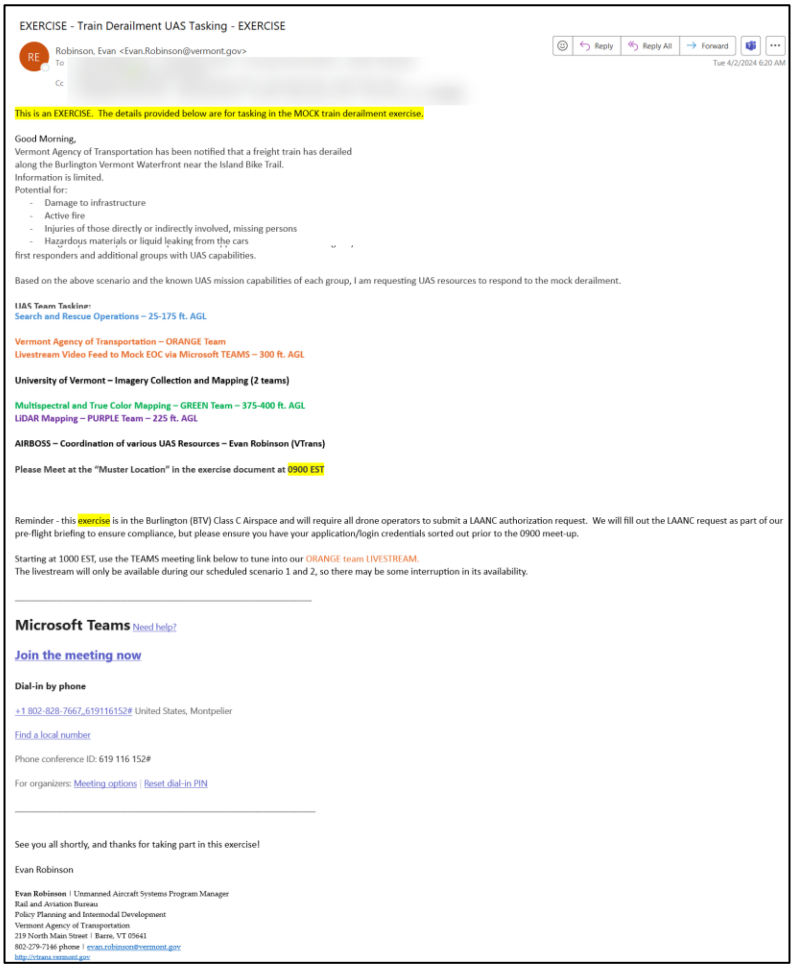
- Aerial video livestreaming to remote emergency command facility to provide SA.
- UAS SAR activities utilizing Electro-Optical (EO)/thermal video.
- EO or "true-color" imagery collection for mapping to inform response and reconstruction efforts.
- Multispectral imagery collection for mapping extent of spilled substances, if any.
- UAS-LiDAR data collection for elevation mapping to inform response and reconstruction efforts.

Two UAS Flight Test Scenarios were planned to demonstrate different levels of complexity of operations. The first scenario had a maximum of two UAS airborne at the same time, with one UAS providing constant live stream video and the other rotating between SAR and mapping. The UAS Air Boss coordinated timing to ensure the collection of all necessary data types. The second scenario increased complexity by having up to four UAS airborne at the same time. Each scenario had up to six use cases conducting UAS operations. The use cases and roles of UAS operations were the same for both scenarios, with the same crew composition in each. Both the coordination of rapid data collection, and communication between flight teams heavily impact the success of disaster response with UAS. For both scenarios, airspace was planned to be partitioned vertically with a buffer of fifty feet between operational zones. It was also planned to have a designated, neutral launch and landing zone where aircraft flight was not permitted except for launch and landing.

A Train Derailment Exercise Plan document was developed by the UVM UAS Team prior to the exercise and was shared with participants beforehand once approved by the FAA. This document provides detailed information on the scenario and objectives, participants roles and guidance, exercise logistics, exercise scenarios, anticipated schedules, safety requirements, a communications plan, and information on evaluation and post-exercise activities.

### *2.28.3 Train Derailment Functional Exercise Execution*

The train derailment functional exercise took place on April 2$^{nd}$, 2024. The mock scenario was initiated with an email at 06:20 EST from the UAS Air Boss explaining the event and requesting UAS response to the scene (Figure 61). This email outlined specific potential issues, assigned mission profiles and altitudes, established a muster location and time, provided a link to where the UAS livestream would be shared, and issued a reminder about the airspace in which the exercise would occur.



EXERCISE - Train Derailment UAS Tasking - EXERCISE

Robinson, Evan <Evan.Robinson@vermont.gov>
To
Cc

Reply | Reply All | Forward

Tue 4/2/2024 6:20 AM

This is an EXERCISE. The details provided below are for tasking in the MOCK train derailment exercise.

Good Morning,
Vermont Agency of Transportation has been notified that a freight train has derailed along the Burlington Vermont Waterfront near the Island Bike Trail.
Information is limited.
Potential for:

- Damage to infrastructure
- Active fire
- Injuries of those directly or indirectly involved, missing persons
- Hazardous materials or liquid leaking from the cars

first responders and additional groups with UAS capabilities.

Based on the above scenario and the known UAS mission capabilities of each group, I am requesting UAS resources to respond to the mock derailment.

UAS Team Tasking:
Search and Rescue Operations – 25-175 ft. AGL

Vermont Agency of Transportation – ORANGE Team
Livestream Video Feed to Mock EOC via Microsoft TEAMS – 300 ft. AGL

**University of Vermont – Imagery Collection and Mapping (2 teams)**

Multispectral and True Color Mapping – GREEN Team – 375-400 ft. AGL
LiDAR Mapping – PURPLE Team – 225 ft. AGL

**AIRBOSS – Coordination of various UAS Resources – Evan Robinson (VTrans)**

**Please Meet at the "Muster Location" in the exercise document at 0900 EST**

Reminder - this exercise is in the Burlington (BTV) Class C Airspace and will require all drone operators to submit a LAANC authorization request. We will fill out the LAANC request as part of our pre-flight briefing to ensure compliance, but please ensure you have your application/login credentials sorted out prior to the 0900 meet-up.

Starting at 1000 EST, use the TEAMS meeting link below to tune into our ORANGE team LIVESTREAM.
The livestream will only be available during our scheduled scenario 1 and 2, so there may be some interruption in its availability.

**Microsoft Teams** Need help?

Join the meeting now

**Dial-in by phone**

+1 802-828-7667,,619116152# United States, Montpelier

Find a local number

Phone conference ID: 619 116 152#

For organizers: Meeting options | Reset dial-in PIN

See you all shortly, and thanks for taking part in this exercise!

Evan Robinson

**Evan Robinson** | Unmanned Aircraft Systems Program Manager
Rail and Aviation Bureau
Policy Planning and Intermodal Development
Vermont Agency of Transportation
219 North Main Street | Barre, VT 05641
802-279-7146 phone | evan.robinson@vermont.gov
http://vtrans.vermont.gov

Figure 61. Train Derailment Exercise UAS Tasking Request email.

Flight operations occurred near Burlington Waterfront Urban Reserve Park, just under 1 Nautical Mile (NM) NE of Downtown Burlington, VT (Figure 62). The center of the operational area was at the coordinates 44.48742, -73.22875. The operational area is owned and managed by the Burlington Department of Parks, Recreation, and Waterfront. A railway runs along the northeastern side of the exercise area and is managed by Vermont Rail Systems (VRS). A recreational path runs along the southwestern side of the exercise site. The exercise flight area was in Class C airspace due to proximity to BTV, which was approximately 3.5 NM SE of the operational area. The UAS Air Boss monitored local air traffic via Airband Radio and had a Visual Observer assist with monitoring the surrounding airspace. Visual Observers were stationed with each flight team to monitor the airspace as well. LAANC airspace authorization up to 400ft was acquired by each flight team on site before beginning flight operations. The UAS Air Boss confirmed LAANC authorization with each team prior to deployment.

The UAS Air Boss utilized Motorola handheld radios and direct verbal communication where possible to maintain communication with all participants. These communication methods had the potential to be used simultaneously as needed to maintain the best SA of all operational partners and positions. The use of multiple communication methods allowed for primary and backup options in case any pathway was deemed inoperable during operations. All communications were monitored and described in detail before every operation to ensure all parties were prepared in case of any issues. The UAS Air Boss and Flight Test Director ensured all communication methods were tested prior to operations and that all parties could transmit and receive before exercise execution. UAS flight teams were instructed to alert the UAS Air Boss prior to and immediately following UAS launch and landing, as well as any mission-critical updates.


Figure 62. Exercise flight operations area in Burlington, VT, outlined with an orange rectangle.

The nominal exercise schedule was outlined in the planning documents for the event (**Error! Reference source not found.**). A detailed exercise schedule with descriptions of each stage was included in the Train Derailment Exercise Plan that was shared with all participants prior to the exercise. The UVM UAS Team arrived at the exercise location at 08:00 EDT to set up exercise infrastructure and equipment and to direct other participants where to park and set up for operations. Participants arrived and a Brief was led by the Flight Test Director and the UAS Air Boss at 09:30 EDT, which included a safety brief, introductions, and assigning VO and Evaluator locations. Communication capabilities and methods, along with Scenario 1 plan, were reviewed as a group before commencing the exercise.

Supporting equipment such as traffic cones, handheld radios, an Airband radio, remote ID broadcast modules, high visibility vests, launch pads, laptops, first aid supplies, easy-up tents, and folding tables were supplied by UVM and VTrans. USAR VT-TF1 came equipped with an operations trailer, external monitor, tent, power generator, and a Starlink system. Both fixed-wing and multirotor UAS were deployed for flight operations and were piloted by small teams from the UVM UAS Team, VTrans, and USAR VT-TF1. All aircraft were operated within line of sight and in accordance with Part 107 regulations. All systems were standard remote identification UAS or equipped with a remote identification broadcast module and operated in accordance with 14 CFR 89.110.

| Start | End | Schedule |
|---|---|---|
| 700 | 730 | Meet at UVM |
| 730 | 800 | Head to Site |
| 800 | 830 | Site Setup |
| 830 | 900 | |
| 900 | 930 | |
| 930 | 1000 | Brief |
| 1000 | 1030 | Flight Operation Scenario 1 |
| 1030 | 1100 | |
| 1100 | 1130 | |
| 1130 | 1200 | |
| 1200 | 1230 | Debrief |
| 1230 | 1300 | Lunch |
| 1300 | 1330 | |
| 1330 | 1400 | Brief |
| 1400 | 1430 | Flight Operation Scenario 2 |
| 1430 | 1500 | |
| 1500 | 1530 | |
| 1530 | 1600 | |
| 1600 | 1630 | Debrief |
| 1630 | 1700 | Teardown |
| 1700 | 1730 | |

Figure 63. Nominal Flight Test Schedule.

Figure 64. Pre-exercise safety briefing.

#### 2.28.3.1 Exercise Scenario 1

The primary objective of Scenario 1 was to carry out flight operations with a maximum of two UAS airborne at the same time. This scenario served as a building block for Scenario 2, in which communication and overall operation would be improved upon. An anticipated flight operations schedule was included in the FAA Test Plan document for this exercise. An accurate schedule of flight operations carried out during the functional exercise is represented in Figure 65.

| | SCENARIO 1 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time (EST) | 10:00 | 10:15 | 10:30 | 10:45 | 11:00 | 11:15 | 11:30 | 11:45 | 12:00 | 12:15 | 12:30 | 12:45 | 13:00 |
| UVM eBeeX Team | | | | | Multispectral (400ft) | | | | True Color (400ft) | | | | |
| UVM AltaX Team | | | | | | | LiDAR (Not collected) | | | | | | |
| VTrans Team | Live Stream (300ft) | | | | | | | | | | Hotwash | | |
| USAR Team | | Search and Rescue (25-175ft) | | | | | | | | | | | |
| UVM "Red" Media Team | | | | | Red Team* | *Time unknown to participants | | | | | | | |

Figure 65. Scenario 1 flight operations schedule.

Launch and landing locations for each flight team are depicted in Figure 66. Launch and landing locations are outlined in red and overlaid processed EO imagery collected by UAS during the exercise.


Figure 66. UAS flight team launch and landing zones, outlined in red and overlaid UAS EO imagery.

A UAS operated by the VTrans UAS Team provided constant live stream video to a simulated EOC throughout the duration of Scenario 1. This VTrans team consisted of three crew members – an RPIC, a VO, and a notetaker that also supported radio communications between the team and the UAS Air Boss. VTrans operated a DJI Mavic 3 Enterprise with integrated EO camera for the live stream and overwatch at approximately 300 feet AGL, which offered SA and documentation of the initial response. The live stream video was shared with a simulated EOC through the following method that VTrans had previously utilized. Prior to the exercise, Microsoft Teams (MS Teams) application was downloaded onto their UAS controller that has an integrated screen and a MS Teams meeting invite was created and shared. At the start of the exercise, the RPIC joined the MS Teams meeting from the UAS controller. Before launching the UAS, the RPIC shared their controller screen via the MS Teams call and continued to share the screen for the duration of the scenario. This setup could allow anyone with the link to join the Microsoft Teams call and record the meeting, therefore recording the UAS controller livestream. The UAS livestream was continuous during the scenario, except for when it was landed to change the battery. For sustained livestream overwatch, two UAS could be operated to provide near-seamless video coverage.

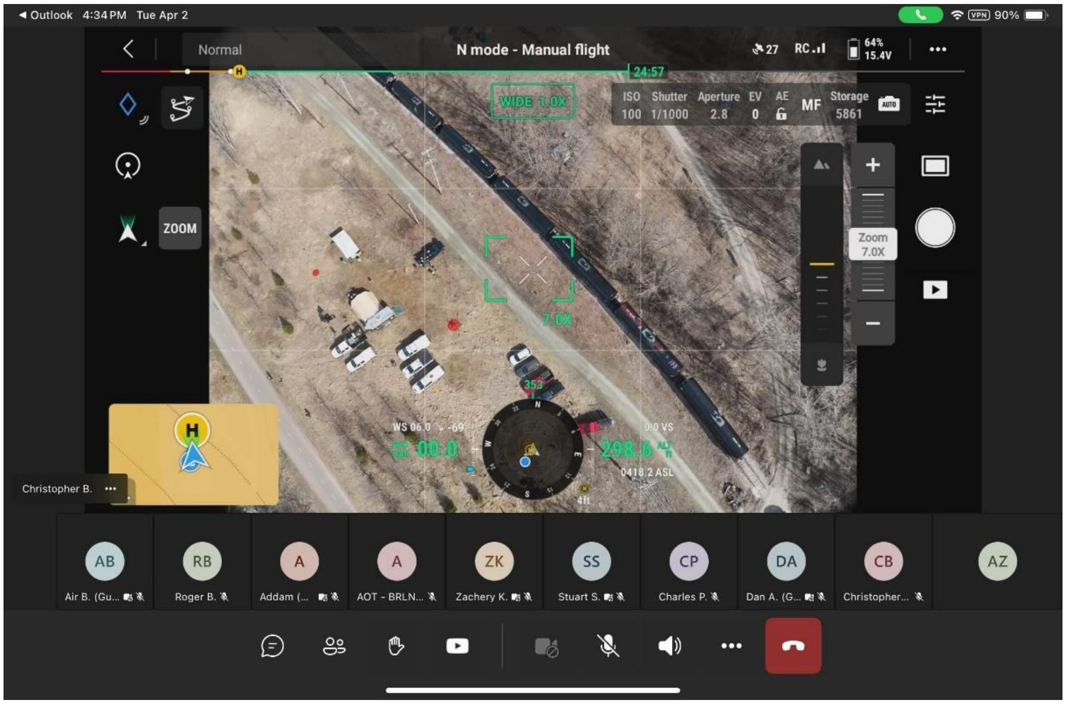



Figure 67. UAS Livestream as displayed in Microsoft Teams meeting.

The second UAS operation in Scenario 1 was led by the USAR VT-TF1 team for SAR and focused on a smaller region of the flight area. The USAR VT-TF1 team consisted of an RPIC, up to two people viewing the UAS SAR live feed, one geospatial data manager, and up to four observers. National Institute of Standards and Technology (NIST) test lane apparatuses served as the SAR "targets" and were placed in the flight area before the exercise began. For this scenario, the RPIC executed a programmed mapping flight with a DJI Mavic 2 Pro Dual with integrated EO sensor to capture imagery and video between 25-175 feet AGL. During the flight, additional crew members viewed the live video feed on an external monitor. The UAS controller screen was mirrored on the external monitor through an HDMI connection. If crew members identified an item of interest, they attempted to direct the RPIC to pause the programmed mission for closer real-time evaluation with EO video. The approximate coordinates of these locations of interest were then relayed to the UAS Air Boss via radio communication.


Figure 68. Live video feed from sUAS displayed on TV monitor for real-time analysis by member of USAR VT-TF1.

Once SAR operations concluded, the UAS Air Boss tasked the first UVM Team with multispectral imagery mapping. The UVM eBee X Team was comprised of an RPIC and a VO, both of which were responsible for radio communications. Multispectral mapping was conducted with the AgEagle eBee X fixed-wing UAS and Micasense RedEdge-MX 5-band multispectral sensor. Due to the space needed to launch and land this fixed-wing platform, a separate launch and landing area was determined before the start of the exercise (Figure 66). An automated mapping flight plan covering the entire exercise area at an altitude of 400ft AGL was generated by the team in AgEagle's eMotion software. When equipped with this sensor, the AgEagle eBee X fixed-wing UAS platform is not compliant for OOP FAA Category 3. Using VOs and ensuring that the launch and landing zone was located away from pedestrian areas, the team ensured that the UAS did not overfly non-participants during operations. Network connectivity enabled the use of RTK GPS corrections through the Vermont VECTOR VRS network, facilitated by a Verizon MiFi hotspot. Utilizing RTK corrections reduced the time required for post-processing images to ensure alignment and overlay of data products with other data collections.

Figure 69. LZ for fixed-wing mapping team from UVM.

A second UVM UAS team worked with the Flight Test Director to simulate a "rogue" UAS operated by a member of the public or local media entering the test flight area at an unknown location and time to other participants. This 'Red Team' determined when and where to interrupt the exercise to ensure that no actual collisions occurred. The entry of a simulated non-participant aircraft into the flight area served to assess how the UAS Air Boss and flight teams effectively coordinated to loiter or ground all UAS. The DJI Mini 3 Pro with integrated EO sensor was used for this task and entered the flight area from the southeast at 11:07 EDT at an altitude of approximately 200ft AGL (**Error! Reference source not found.**). The "rogue" UAS was identified after 2.5 minutes of flight time by the VTrans livestream team, who then alerted the UAS Air Boss of the unidentified UAS. The UAS Air Boss then commanded all UAS to loiter in place to avoid collision and tasked an emergency manager to locate the "rogue" UAS pilot if possible. At this time in the exercise, the only other airborne UAS were the VTrans livestream small multirotor and the UVM multispectral mapping fixed-wing platforms. The small multirotor was able to hold its position at 300ft AGL and the RPIC on the mapping team commanded the fixed-wing sUAS to circle in place over its landing zone. Once the "rogue" UAS landed and the pilot was

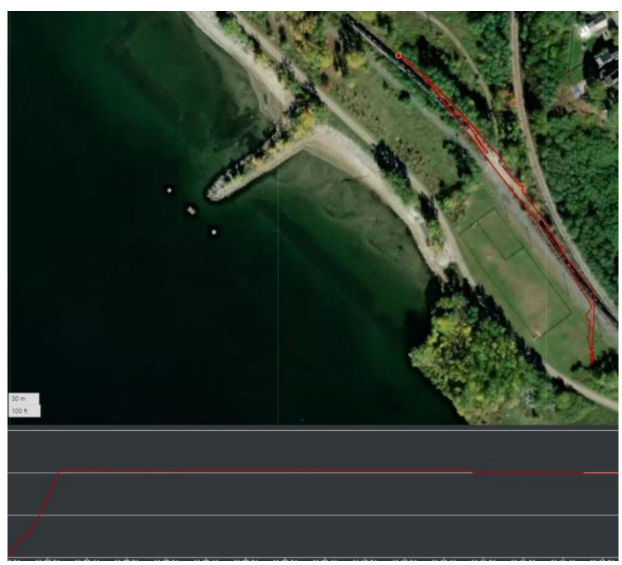


Figure 70. Flight trajectory of 'Red Team' sUAS.

identified, the UAS Air Boss informed all teams that they could resume flight operations. Given that the multispectral mapping mission had been completed before the incursion of the "rogue" UAS, the fixed-wing sUAS was landed and data was copied from the camera to a field laptop.

Upon the completion of multispectral mapping flights, the UAS Air Boss tasked the third UVM UAS team with LiDAR data collection. The UVM Alta X Team consisted of an RPIC and a VO and both were responsible for radio communications. The Freefly Alta X multirotor UAS with YellowScan Surveyor LiDAR sensor was prepared for operations. The Alta X was equipped with a uAvionix pingRID Remote ID broadcast module to operate under CFR 89.115(a). Flight plans were generated in the field on a laptop using UgCS flight planning software. The flight crew was unable to achieve a connection between the USB ground station and the Alta X autopilot on the Dell laptop they were using. Though UVM staff had confirmed that the UgCS software was running as expected during set up of the laptop, the UAS staff did not test the connection between the Alta X ground modem and UgCS when using a USB-C to USB-C cable, which was the only cable available. The flight crew continued troubleshooting for approximately 15 minutes but was unresolved in the field, likely due to limitations of the drivers or USB chipset on the rugged laptop. The flight crew was prepared with a DJI M300 system to use as a backup platform and began to prepare this new system for flight with the Yellowscan Surveyor Ultra sensor. During pre-flight checks, it was determined that the sensor was inoperable as the result of a corrupted firmware update that was applied the previous week. The sensor was not flight tested following the firmware update. As a result of these challenges, the Air Boss made the decision to not execute the LiDAR mission profile during Scenario 1.

Figure 71. FreeFly Alta X system during failed pre-flight checks.

Once it was determined that the LiDAR use case would not be executed in Scenario 1, the UAS Air Boss tasked the UVM eBee X Team with EO imagery mapping. The AgEagle eBee X fixed-wing sUAS equipped with the AgEagle SODA 3D EO sensor was deployed for mapping. The separate launch and landing area used earlier in Scenario 1 was utilized again. An automated mapping flight plan covering the entire area of interest at 400ft AGL was generated in eMotion flight software at the start of the scenario. The AgEagle eBee X fixed-wing UAS platform is Category 3 OOP-compliant when utilized with the SODA 3D sensor. Similarly to the multispectral mission, RTK corrections were enabled. Once the EO mapping mission was complete, the UAS was landed and the UAS Air Boss was notified of mission completion. EO mapping data was copied from the sensor to a field laptop.

Following the completion of Scenario 1, the UAS Air Boss led a debrief with all participants and discussed key lessons learned from Scenario 1 and what could be improved for Scenario 2 in the afternoon. General takeaways included that radio communication between the UAS Air Boss and UAS flight teams could be clearer and more concise. The Assistant UAS Air Boss having strong aviation background and clear radio communication knowledge was very valuable.

#### 2.28.3.2 Exercise Scenario 2

Participants took a lunch break before returning to the exercise flight area for Scenario 2 briefing and preparation. The brief was led by the UAS Air Boss at 14:00 EDT and included assigning VO and Evaluator locations and reviewing the Scenario 2 plan as a group. The goal of Scenario 2 was to improve the overall response time by increasing the amount of UAS operations occurring at the same time. UAS mission profiles and flight team compositions remained the same from Scenario 1 to Scenario 2. Scenario 2 increased complexity by having up to four UAS airborne at the same time. An accurate flight operations schedule from the exercise is shown in Figure 72.

| | SCENARIO 2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Time (EST) | 14:30 | 14:45 | 15:00 | 15:15 | 15:30 | 15:45 | 16:00 | 16:15 | 16:30 |
| UVM eBeeX Team | | | Multispectral (400ft) | | True Color (Not collected) | | Hotwash | | Takedown |
| UVM AltaX Team | | | | LiDAR (225ft) | | | | | Takedown |
| VTrans Team | Live Stream (300ft) | | | | | | | | |
| USAR Team | | Search and Rescue (25-175ft) | | | | | | | |
| UVM "Red" Media Team | | | | | | | | | |

Figure 72. Exercise Scenario 2 flight operations schedule.

UAS launch and landing zones utilized were unchanged from the initial scenario. The first UAS mission for Scenario 2 was livestream video collection tasked by the UAS Air Boss at 14:30 EDT. Consistent with Scenario 1, the VTrans team operated a DJI Mavic 3 Enterprise with integrated EO camera to provide constant live stream video to a simulated EOC throughout the scenario. The mission was flown at approximately 300ft AGL and the livestream video was shared through the same Microsoft Teams method utilized in Scenario 1. Battery management and communicating urgency to the UAS Air Boss regarding the need to land due to declining battery levels was challenging for this team in Scenario 2.

The second UAS was deployed at 14:45 EDT led by USAR VT-TF1 for a SAR mission. The team operated a DJI Mavic 3 Enterprise with both EO and IR integrated sensors as opposed to the DJI Mavic 2 Pro Dual utilized in Scenario 1 for solely EO video capture. Also building on the experience from Scenario 1, USAR VT-TF1 determined that flying a grid pattern would provide better and more efficient coverage of the area. The RPIC executed a programmed mapping flight plan and captured images of the search area. It was observed that the RPIC and VOs did not maintain eyes on the aircraft throughout the flight, although the UAS was always within VLOS range. At one point in Scenario 2, they were asked by the UAS Air Boss where the aircraft was located, and the RPIC and VOs struggled to physically establish visual contact with the sUAS.

Approximately 15 minutes into the SAR operations, the UAS Air Boss tasked the UVM eBee X Team with collecting multispectral mapping imagery at 15:00 EDT. The AgEagle eBee X fixed-wing sUAS with Micasense RedEdge-MX 5-band multispectral sensor was utilized in both scenarios. The same launch and landing area was used, as well as the same automated mapping flight plan from Scenario 1.

At 15:15 EDT, the UAS Air Boss requested LiDAR collection from the UVM LiDAR Team. The team had relocated their LZ away from the USAR team's LZ location to be closer to their supporting equipment. The team conducted the mapping mission at 225ft AGL with a DJI M300 RTK multirotor UAS equipped with a YellowScan Mapper LiDAR sensor, proving the value in having backup UAS and sensors at hand after the technical challenges experienced during Scenario 1. This mission marked four simultaneous UAS operations in shared airspace during Scenario 2. Radio communications became increasingly hectic and hard to follow as more UAS entered the airspace.

At approximately 15:30 EDT, both the SAR and multispectral mapping missions concluded. USAR VT-TF1 landed on their platform and had their geospatial data manager review the individual images immediately after the flight's conclusion to identify items of interest. The coordinates of the locations of interest were relayed to the UAS Air Boss. The UVM eBee X Team landed the fixed-wing sUAS, copied the multispectral data to a field laptop, and swapped out the battery and the sensor for the AgEagle S.O.D.A. 3D EO camera in preparation of tasking for EO mapping. The UVM LiDAR Team completed LiDAR collection, landed their platform, and copied the data to a field laptop. The UAS Air Boss communicated the end of the VTrans livestream flight and conclusion of the exercise. Due to miscommunication, the UAS Air Boss did not task the UVM eBee X Team with EO mapping, which was therefore not carried out during Scenario 2. Although EO imagery was not acquired, it is possible to generate EO mapping imagery from the discrete blue, green, and red bands captured from the 5-band multispectral sensor previously deployed. Although many typical UAS-multispectral sensors provide lower resolution imagery compared to dedicated EO sensors, solely collecting multispectral imagery may be sufficient depending on the scenario and resolution requirements.

With the completion of Scenario 2, all participants reconvened to carry out a hotwash.

#### *2.28.4 Train Derailment Functional Exercise Follow-Up Activities, If Applicable*

The day after the mock train derailment exercise, a debrief meeting was held with personnel from the UVM UAS Team, VTrans, the FAA, USAR VT-TF1, UVM Risk Management, and the exercise evaluators from KSU and the UAH. The session focused on reviewing the exercise's outcomes, discussing challenges encountered, and identifying areas for improvement to enhance future response efforts.

One topic of conversation focused on the development of a Vermont UAS Working Group. A rough list of potential participants was determined including UVM, VTrans, USAR VT TF-1, Vermont HAZMAT, Vermont Emergency Management, UVM Risk Management, Burlington Police Department, Burlington Fire Department, and other local jurisdictions with emerging UAS programs. The objective of the working group would be to involve a diverse range of groups to build statewide relationships, conduct joint exercises, and increase awareness of UAS capabilities, fostering knowledge and trust ahead of future emergencies. The VTrans UAS Program Manager offered to lead coordination efforts and set an initial meeting date in the months following the exercise.

Where applicable, all teams were responsible for storage, processing, and dissemination of their data after collection. UVM was responsible for processing imagery and LiDAR collections to produce deliverables for generation of a web application. A UAS Research Technician accessed and imported the multispectral imagery from the eBee X flight in Scenario 1 to create a new project in Pix4Dfields photogrammetry software on a high-powered workstation (12 CPU cores, 128GB RAM, discrete GPU). The total time to generate 5-band orthoimagery using this software was not recorded but is estimated to be less than 45 minutes. Upon completion of the processing, a UAS Research Technician made a copy of the orthoimagery file (GeoTiff format), adjusted the naming of the file to meet the SAL's standard conventions, and imported the multispectral orthoimagery to an ArcGIS Pro project. The combination of bands was adjusted to display a false-color composite, with the red color gun displaying near-infrared (NIR) light. Next, they completed the task of publishing the imagery to a tile service. The publishing of this tile service to ArcGIS Online was not recorded but estimated to be less than 60 minutes.

Figure 73. Multispectral orthoimagery displayed as false-color composite (NIR as red color gun).

Simultaneously, a UAS Research Specialist began orthoimagery processing of the true-color imagery using Esri SiteScan cloud-based processing solution. The time to upload the images, complete processing, and publish the orthoimagery to ArcGIS Online was not recorded but estimated to be less than 2 hours, with just 15 minutes of active time.

Figure 74. True-color orthoimagery, with inset displaying identification number of individual train car.

The LiDAR data processing began with PPK corrections of the sensor flight trajectory using Applanix POSPac software and data from a local GNSS base station. A point cloud was generated using YellowScan CloudStation software and the corrected trajectory. Utilizing LAStools software, the point cloud was classified to differentiate between ground and above ground features, and then used to generate a digital elevation model (DEM) representing bare earth and a digital surface model (DSM) representing the topography of all features. Finally, the resulting point cloud was colorized in QT Modeler using the orthomosaic. The total time to complete these processing steps was not recorded, but it is expected that these data products would not be able to be prepared for at least 24 hours following completion of the data collection missions. The LiDAR derived data products allow for 3D visualization of the scene and for highly detailed measurements of distance, height, area, and volume. Due to the high accuracy of these products (often in the range of 1-2 inch in horizontal and vertical planes), comparisons can be carried out to determine topographical changes that may have resulted from a derailment event.

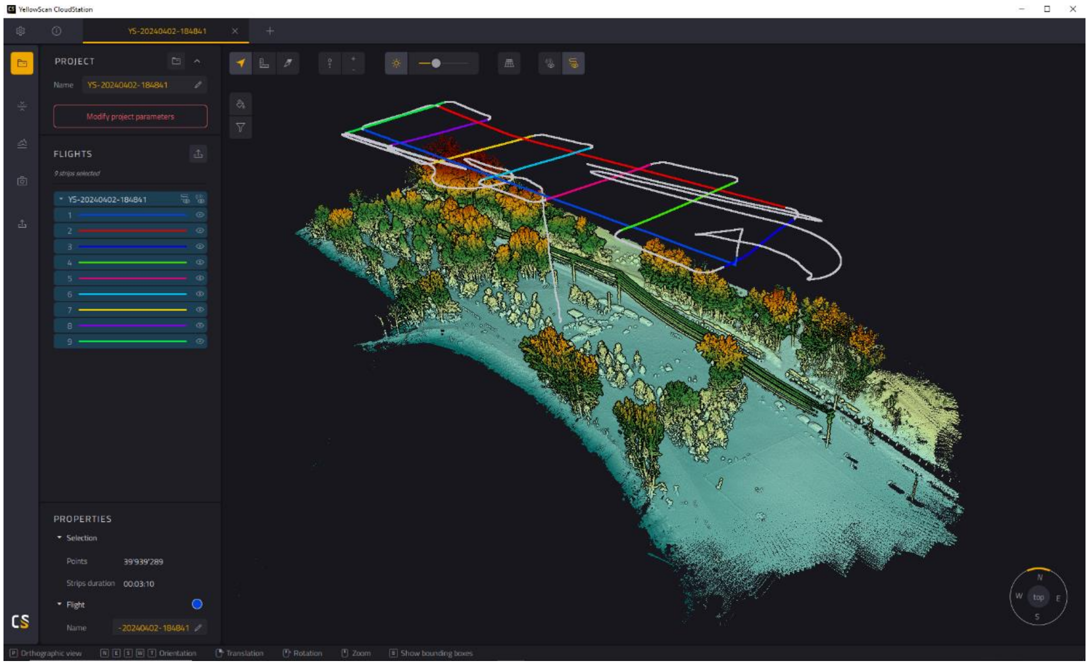



Figure 75. Intermediate step of LiDAR data processing in Yellowscan Cloudstation software, displaying flight lines above and initial point cloud below.

Both sets of orthoimagery and the derived LiDAR data were shared to an ArcGIS Online group created by UVM. The publisher account at VCGI was invited to the group, along with UVM personnel, to allow for direct sharing to the geospatial agency and the generation of a web mapping application with the data.

#### *2.28.5 Lessons Learned from the Train Derailment Functional Exercise, Including Responses to Research Questions*

The Lessons Learned from this exercise will be addressed in a separate Lessons Learned document which is included as an appendix to this document. (See section 8.6)

### 2.29 3-5-Sep-2024, Functional Exercise, Wildland Fire: Controlled Burn, Pontotoc, MS, Conducted by NMSU and MSU

The purpose of this functional exercise was to explore the potential of UAS as an effective response tool in a controlled burn scenario:

*"A tract of land has overgrown and presents a potential future wildfire hazard. A local forester determines that a prescribed burn would be beneficial to address the potential hazard. Through controlled application of fire by a team of fire experts under specified weather conditions, the prescribed burn will restore health to ecosystems that depend on fire. The forester develops a burn plan that identifies or prescribes the best conditions under which trees and other plants will burn to get the best results safely. The burn area is pretreated with a chemical agent several weeks in advance to enhance the prescribed burn operation. The burn plan considers temperature, humidity, wind, moisture of the vegetation, and conditions for the dispersal of smoke. Prescribed fire specialists compare conditions on the ground to those outlined in burn plans before deciding*

*whether to burn on a given day. UAS are used for several support functions before, during and after the burn.*

*Flights before the burn are used to map the area and build mosaiced maps and 3D models using EO, VNIR, and LiDAR sensors. These provide a record of the area before the burn. This information can be used to calculate fuel load. Two different UAS functions are exercised during the burn to provide the Incident Commander or Burn Boss actionable information. First an overwatch UAS (tethered and/or free flight), and second by a free flight UAS that can be commanded to look at specific locations, features, and events via a visual camera and thermal infrared camera. The same set of flights completed before the burn are repeated to provide a record of the area post burn and can be used to assess effectiveness of the burn.”*

### *2.29.1 Objectives of the Wildland Fire: Controlled Burn Functional Exercise*

UAS types, sensors, and needs required to support a wildland fire controlled burn were previously detailed to the FAA in the A28 reports and multiple subsequent Technical Interchange Meetings with the FAA. The continuity from this previous work and description of the Mission Procedures/Approach is shown in Figure 76, which outlines the required UAS and associated sensors needed to support the end goals of a prescribed burn exercise. The various desired support functions are outlined and the approaches to accomplish the assigned elements are detailed. The muscle movements included pre and post mapping/modeling with various sensors, overwatch during the burn, and real time visuals during the event of both Electro Optical (EO) and Thermal Infrared (TIR). Additional desired UAS functions identified in A28 were unable to be tested due to flight and approval restrictions, including fire ignition from a UAS, and carrying fire retardant materials.

Using the previously defined Mission Procedures/Approach, the primary and secondary objectives for this exercise are outlined below:

The primary test objectives were:

1. Provide flight overwatch through mission.
2. Provide real time visuals (operator directed) of event.
3. Provide pre and post mapping of event location.
4. Provide guidance and lessons learned from flight operations.

Secondary test objectives were:

1. Assessment of the data products and quality.
2. Assess positioning and other safety and performance metrics.

## Mission Procedures/Approach

## Source planning information

*sUAS#1*: Fixed tethered view of all of the missions
EO and TIR data shared through tethered system
Field of View allows full view of all operations [take-off, flight, and landings]; Fly VLOS or EVLOS under VFR conditions; Will stay airborne until operations complete

*sUAS #2A*: 1st flight; VLOS operations
EO/VNIR/TIR camera with LiDAR; Provide real-time data and build mosaiced maps and 3D models
Post flight: LiDAR point clouds to assess local vegetation and canopy near to burn areas
Flown from launch site for use by all sUAS; Route defined to cover the area that will be burned ; VFR conditions as will be VLOS

*sUAS - ~~#3A and~~ #4A* [~~#3A - Carry fire ignition material;~~ #4A - EO and TIR payload for eyes on the event]
Part 107 operations, flight #3A at higher altitude to view the full burn area
Fly VLOS or EVLOS under VFR conditions

*sUAS - #2B and #4B* [#2B - EO, VNIR, and TIR payload to map the fire; #4B - EO and TIR payload for eyes on the event]
Part 107 operations, flight #4B to view the full burn area
Flight #2B has defined pattern and also can move based on data from #3B

~~*sUAS - #3B and #4C* [#3B - Carry fire retardant material; #4C - EO and TIR payload for eyes on the event]~~
~~Part 107 operations, flight #4C to view the full burn area~~
~~Flight #3B will move to area needed for retardant based on data from #4B~~

*sUAS - #2C and #4D* [#2C - EO/VNIR/TIR camera with LiDAR; #4D - EO and TIR payload for eyes on the event]
#2C - Provide real-time data & build mosaiced maps/3D models; Post flight: LiDAR point clouds to assess impact to vegetation & any canopy
#4D will watch how #2C maps the edge of fire and collects LiDAR data
#2C follows pattern based of data from flight #4C

Figure 76. UAS and sensors required to support the prescribed burn operations.

### *2.29.2 Planning for and Logistics of the Wildland Fire: Controlled Burn Functional Exercise*

Unlike many of the other functional exercises, a controlled burn exercise is not an "all simulation" or tabletop event. The only way to fully test the proposed UAS support elements is in conjunction and coordinating with an actual live fire event. The combined team supporting this exercise defined a stepwise plan and approach to get to the actual live burn event. The team wanted to test and retest all UAS support elements in advance before deploying to the field for the live burn. Testing was conducted/led by NMSU with support from the UAF-ACUASI and Oregon State University to build and perform a suite of flights to map and analyze wildland fire scenarios. Additional support for the operations is being provided by MSU, KSU, and North Carolina State University. Additional program and consulting support was provided by the UAH and UVM.

The prescribed burn plan of evolving levels of complexity and to enhance maturity before the live burn is outlined in the steps below. In advance of the execution, this approach was presented to the FAA for review and approval and allowed for a logical stepwise advancement. The three elements to complete the integrations, flight testing, data integration, and events before the actual live fire prescribed burn included the following:

- *Dry Run Test:* A full mock event to practice with SOP's, equipment, data collection, processing, and after-action review. This event ran a full up practice with people, equipment, and plans with no fire to ensure team has the production, processes, and post data analysis done correctly.
- *Fire Test:* A simulated event with fire and flares in buckets and many additional heat sources. This allowed the team to test all elements in a proxy configuration and use.
- *Structure Fire Test:* Working with the Las Cruces Fire Department to fly UAS during a planned burn at their training facility. This allowed the team to re-test elements in a proxy configuration with real smoke and fire in use as well as assess sensor performance with smoke obscuration.

The tests outlined above were standalone events but build upon each other. This included the flight preparations (completed over time), system testing and operational checks in advance, onsite setup, flying the actual mission (nominally one to three days), breakdown and closeout of flight operations, post-mission data analysis, and reporting. Support was spread over a period of time leading up to the actual event, during the event, and post-event to close out the activity.

Detailed posttest reports were prepared and submitted to the FAA after these events. These reports were titled, "A52 NMSU Prescribed Burn Dry Run and Fire Tests Report July 2024", and "A52 NMSU Prescribed Burn Structure Fire Test Report July 2024". The team collected many different lessons learned with each event and they were also documented in the individual test reports as well as in the separate Functional Exercise Lessons Learned report. Short synopses of each of these three sets of tests are provided below. It is noted that for all of these flights, a weather station was on site that also measured soil moisture to address one of the initial research questions. Plots of this collected data was included in each test report. It is also noted that the VOs for all of the flight operations were positioned to ensure clear view in all directions.

#### 2.29.2.1 Dry Run Test – Completed July 1 and 2, 2024

The first round of flight testing was conducted in preparation for the prescribed burn exercise and was named the Dry Run Test. This testing and the subsequent Fire Test were documented in one report titled “A52 NMSU Prescribed Burn Dry Run and Fire Tests Report July 2024”. This test was a follow on to the previously defined UAS, functions, LiDAR, Thermal, and EO sensors, and products with a flow down from this previous work. This test specifically focused preparations before a prescribed burn event and the collection of lessons learned. This was the first of three tests with progressing levels of complexity. The Dry Run Test was designed to test the NMSU aircraft, sensors, support equipment, and operational plans.

The Dry Run testing was conducted July 1 and 2, 2024, at the Dona Ana Fairgrounds west of Las Cruces, NM. The main foci derived from the test objectives were to 1) test all of the flight systems, sensors, equipment, and procedures in a simulated mission scenario; 2) collect lessons learned; and 3) assess post processing of the data products. The mission practiced all of the elements required before supporting a prescribed burn. The Dry Run Test objectives are outlined below:

The primary test objectives were:

1. Provide flight overwatch through mission.
2. Provide real time visuals (operator directed) of event.
3. Provide pre and post mapping of event location.
4. Provide guidance and lessons learned from flight operations.

Secondary test objectives were:

1. Assessment of the data products and quality.
2. Assess positioning and other safety and performance metrics.

The Dry Run Test was executed exactly as planned with 13 flights performing multiple different types of mapping missions and overwatch over two days. All of the desired muscle movements and system checks were completed. Figure 77 presents a Google Earth view of the racetrack testing area at the Fairgrounds. The flight days were very hot, and equipment temperatures were checked constantly. Figure 78 shows the tethered UAS in flight while the PIC takes a temperature measurement of the systems. Figures 79 and 80 show the Trinity VTOL aircraft operations. Two of the three different sensors required calibration before flying the planned mission profiles. Composite images were processed post flight. Figure 81 presents a LiDAR composite image from the X-6 UAS. Figure 82 presents an Ortho EO image generated from the Trinity. Figure 83 presents a thermal image from the Trinity. Figure 84 presents a LiDAR image from the Trinity

All of the fight missions were completed safely under Part 107 operations. There were no safety issues. Lessons learned focused on equipment, flight operational planning, execution, and some system limitations due to heat. The few lessons learned that impacted how to proceed with future missions included the following:

- For the Trinity aircraft, each flight must be closed out upon completion before flying again to ensure no loss of data.
- Google is helpful but may not be accurate to actual terrain profile and elevations.
- Takeoffs, landings, and mission overflight directions need to be coordinated day by day due to local wind speed and direction to ensure safe and successful flights.
- The tethered UAS Thermal camera stops showing the heat map if all temperatures are similar.
- 20 knots ground speed is too high for colorization of X6 data.

- SX6 (ZD850) on the tether is limited on altitude due to increased weight of tether. It was found that 242 feet is above the capacity of the current equipment. Post mission updates were made to address this issue.

Many additional items were captured in the lessons learned. All of the desired elements and system checks were completed. All of the primary and secondary objectives as outlined before the missions were met in advance of the planned prescribed burn exercise. Successful completion of these operations, with subsequent integration of lessons learned, lead to the Fire Test.

Figure 77. Racetrack area at the Fairgrounds.


Figure 78. Component temperature measurement in flight using hand held FLIR.

Figure 79. Takeoff and pre-flight sensor calibration of the Trinity.


Figure 80. Trinity flight operations.


Figure 81. LiDAR composite image from the X-6.

Figure 82. Ortho EO from the Trinity.

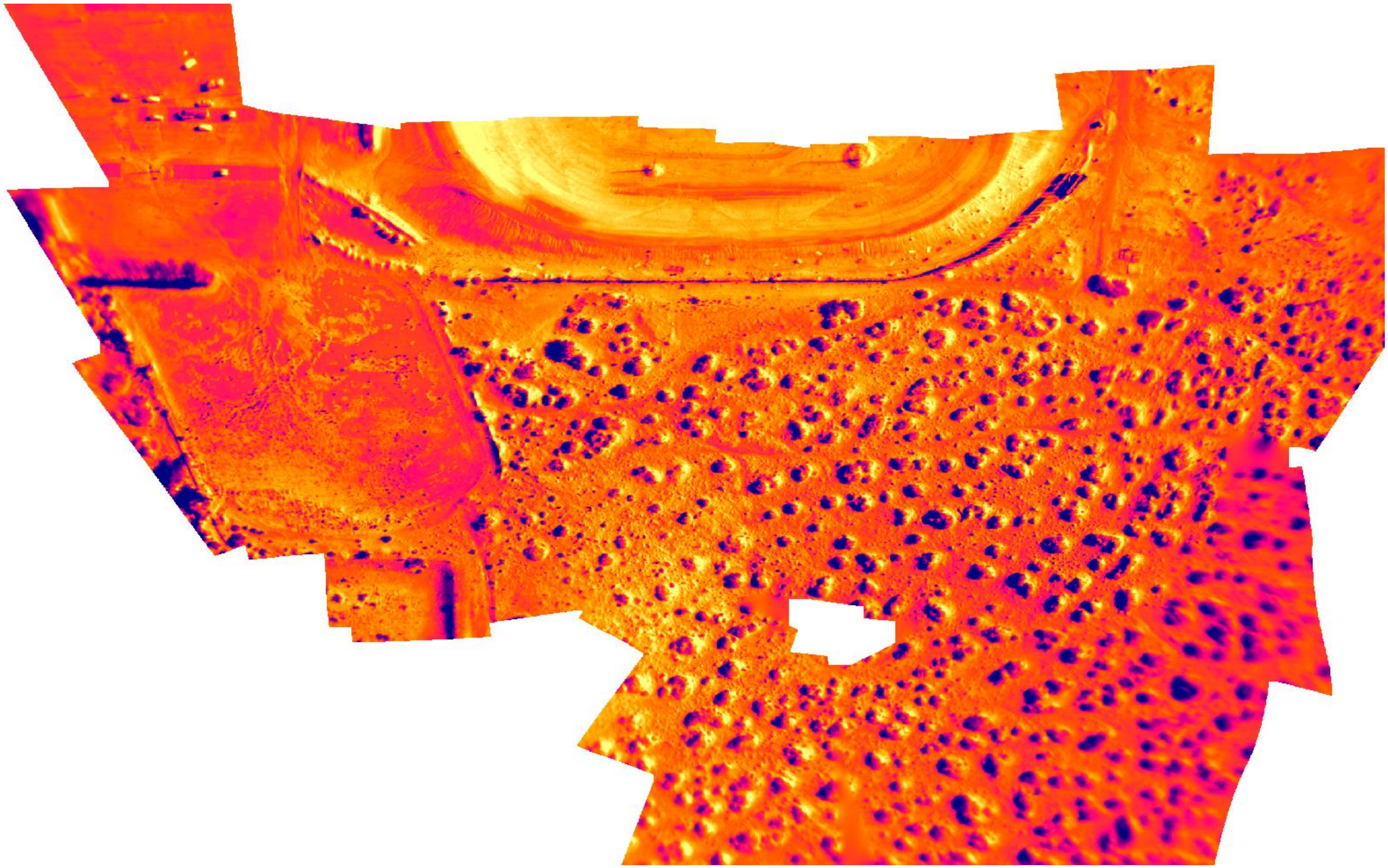


Figure 83. Thermal from the Trinity.

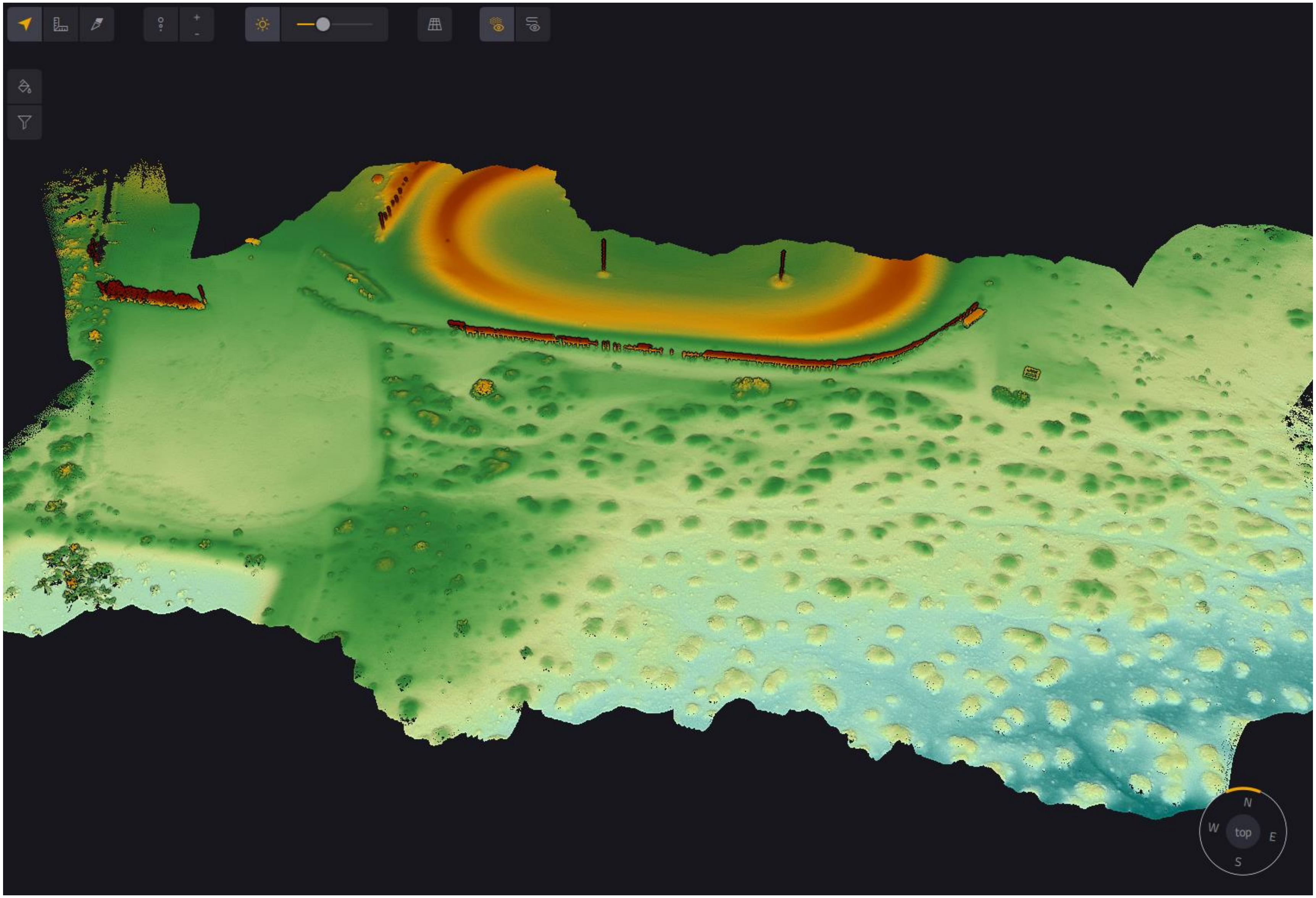


Figure 84. LiDAR from the Trinity.

#### 2.29.2.2 Fire Test – Completed July 15 to 17, 2024

The second round of flight testing was conducted in preparation for the prescribed burn exercise and was named the Fire Test. The research team has coordinated with multiple other universities to test out all of the systems, equipment, sensors, procedures, and coordination in advance of a future prescribed burn. The goal here was to exercise all of the elements before the required full event demonstration and to capture any specific and general cautions and improvements to the support. The Fire Test included the addition of UAS and flight support from UAF, and mission support from Oregon State University for collection of lessons learned. Additional observers from UAH and the FAA were on site.

The Fire Test was conducted over three days, July 15 to 17, 2024 with a briefing and integration on day one followed by post integration check flights. The test flights took place at the Jornada Research Range west of Las Cruces, NM. The Fire Test was executed as planned with 17 flights over the following two days performing multiple different type of mapping missions, overwatch, and the addition of an aircraft that could be flown to look at desired locations with a thermal and EO cameras. The mission objectives were similar to the Dry Run Test, but with a wider assortment of aircraft, more personnel from the broader research team, and the addition of fire and live heat sources on the ground. The mission practiced all of the elements required before supporting a prescribed burn. The Fire Test objectives are outlined below:

The primary test objectives were:

1. Provide flight overwatch through mission.
2. Provide real time visuals (operator directed) of event.
3. Provide pre and post mapping of event location.
4. Provide guidance and lessons learned from flight operations.

Secondary test objectives were:

1. Assessment of the data products and quality.
2. Assess positioning and other safety and performance metrics.

Figure 85 shows the UAF Super Volo being prepared for flight. This aircraft provided overwatch by circling the flight area for the entire operational period. The first day it was flown at 400 ft AGL. This was found to be a bit too low for optimal performance and viewing of the test area. On the second day, it was flown at 1,200 ft AGL under the UAF Flight Test Site COA. Figure 86 shows the Trinity aircraft before launch for one if its mapping missions.

The burn bin with the fire and the overflight of the Matrice aircraft are shown in Figure 87. Figure 88 shows hand held FLIR measurements of the fire at different times during the day. There were many heat sources used during these operations and they were recorded throughout the day. Figure 89 presented various temperatures measured and captured on the hand held FLIR during the day. From the upper left corner and going clockwise the images are a road flare (535°F), generator (114°F), person (97.7°F), ground temperature in the morning (86.3°F), ground temperature later in the day (106°F), charcoal grill (350°F), gas grill side (281°F), and gas grill grate (424°F).

Logs of the temperatures of the various heated elements were made throughout the test period. These were to provide ground truth information for the post processing and not to provide a detailed time history of the various elements. The two different hand held FLIR's provided consistent data between the two instruments and correlated well with the remote measurements on the Matrice. There were some objects on the ground that were too small or the heat signature too diffuse for an accurate in-flight measurement. It should be noted that the point was not to measure exact temperatures, but to identify relative hot spots.

Figure 90 is a post processed LiDAR image from the X-6 with colorization. Figure 91 is an ortho photo zoomed in to fire from 6/17/2024 from the Trinity UAS. Figures 92 and 93 present thermal images captured during the tests. The second of these images shows the mapping of GPS positions of heating elements extracted from photographs on the thermal map. An excellent correlation.

The two days of missions practiced all of the elements required by the larger team before supporting a prescribed burn. Post flight data products were produced. All of the desired muscle movements and system checks were completed except the tethered system that had equipment issues. Lessons learned focused on equipment, flight operational planning, execution, communication, and measurement of hot spots during flight. All of the primary and secondary objectives as outlined before the missions were met in advance of the planned prescribed burn exercise.

Figure 85. Preparing the Super Volo for flight.


Figure 86. Trinity before takeoff.


Figure 87. Matrice flight overlooking the burn bin.

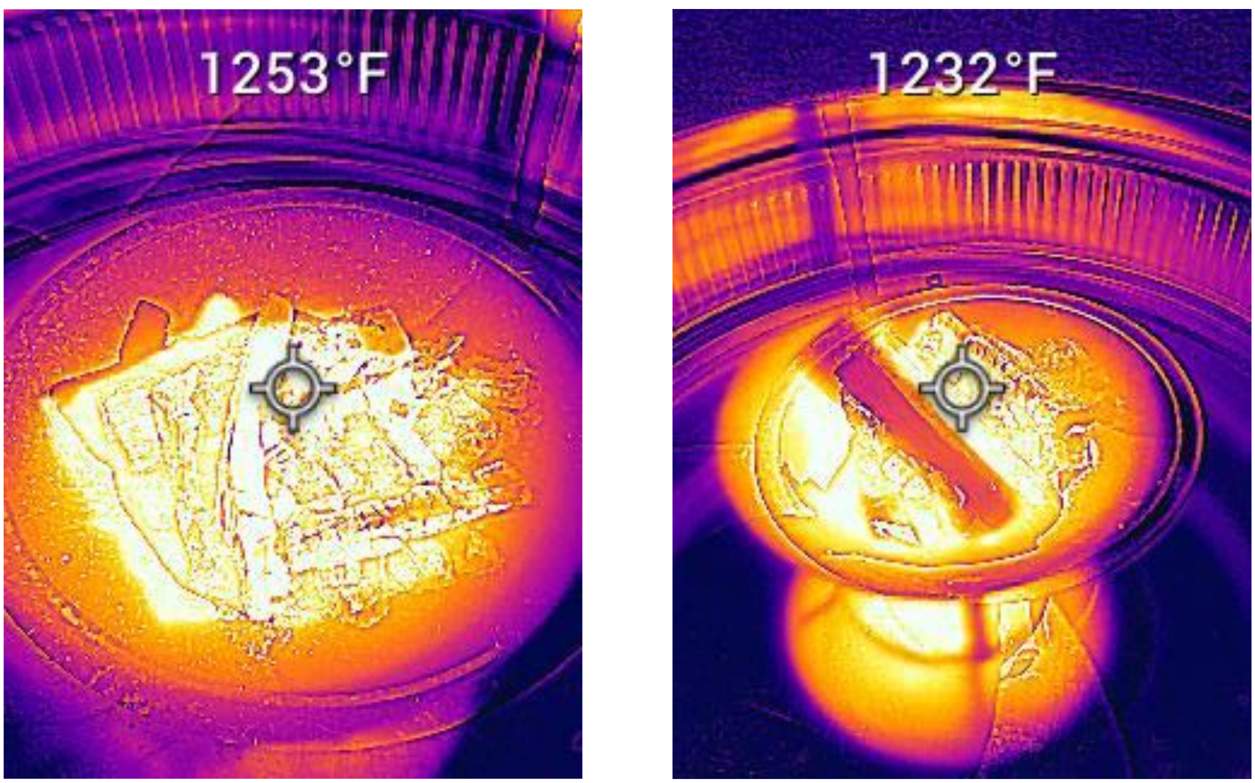



Figure 88. Hand held FLIR measurements of the fire at different times during the day.

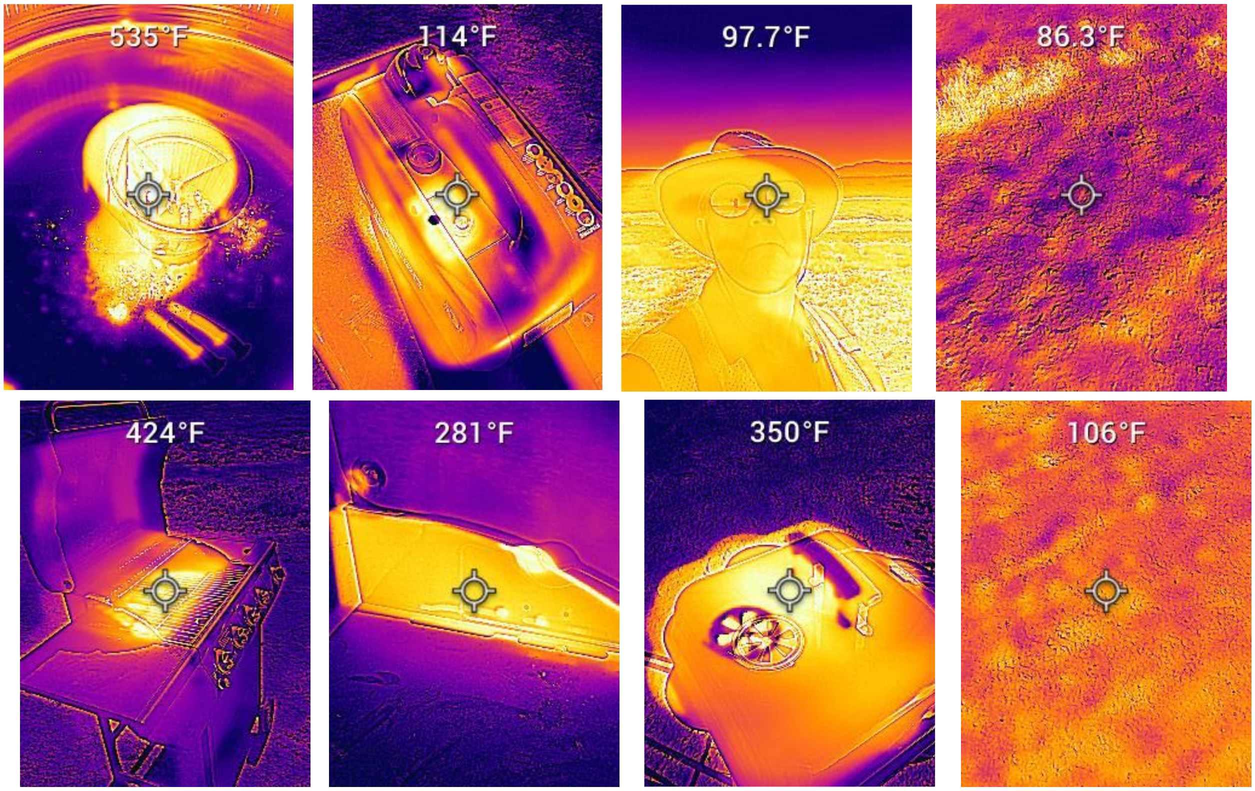


Figure 89. Various heat signatures measured with the hand held FLIR during testing.

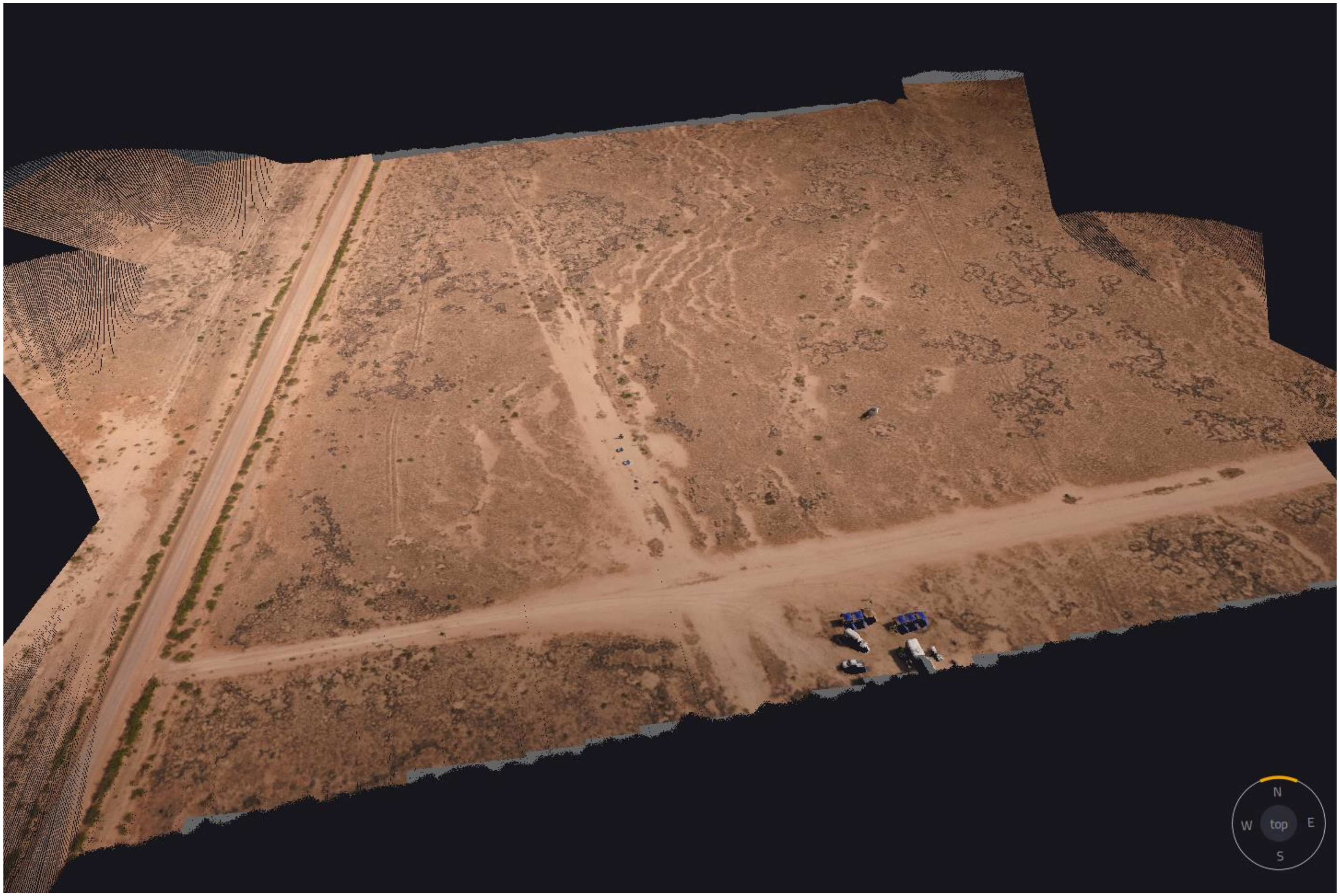



Figure 90. LiDAR from the X-6 with colorization.

Figure 91. Ortho Photo Zoomed in to Fire from 6/17/2024 Trinity UAS.

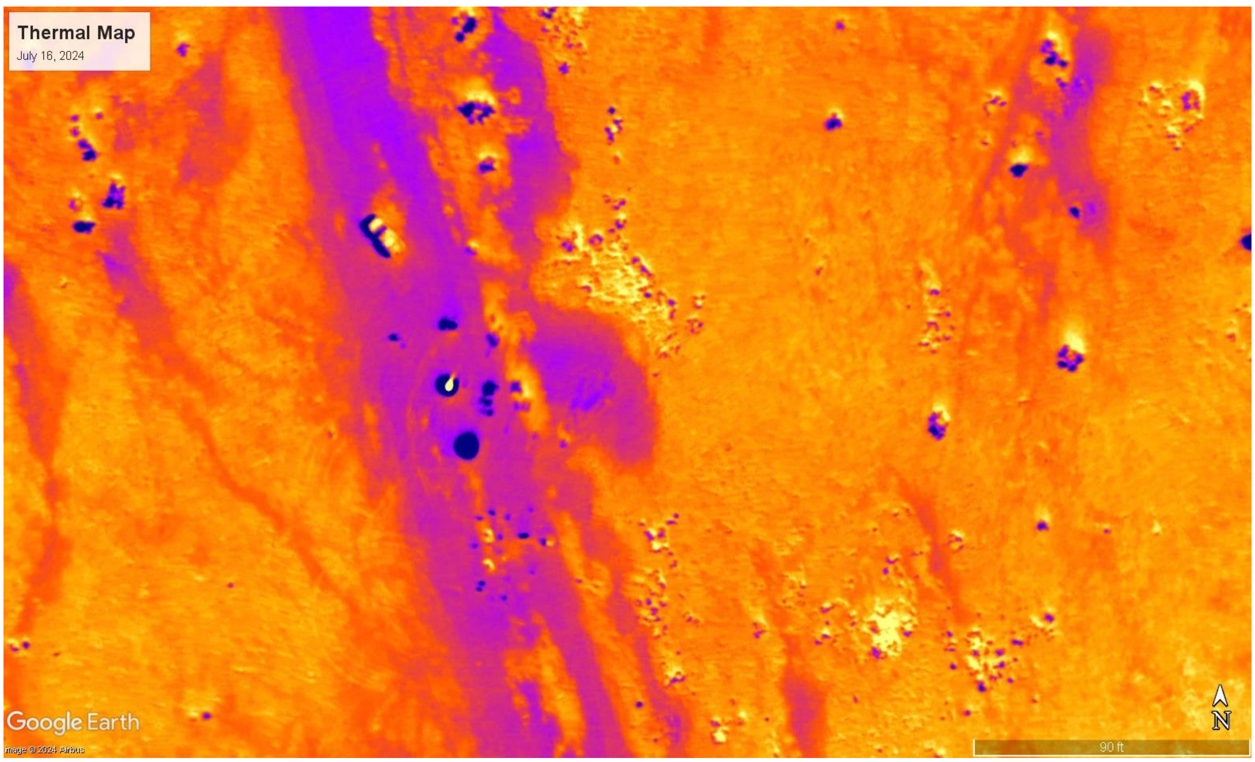



Figure 92. Temp. Scale 39.6C to 51.7C.

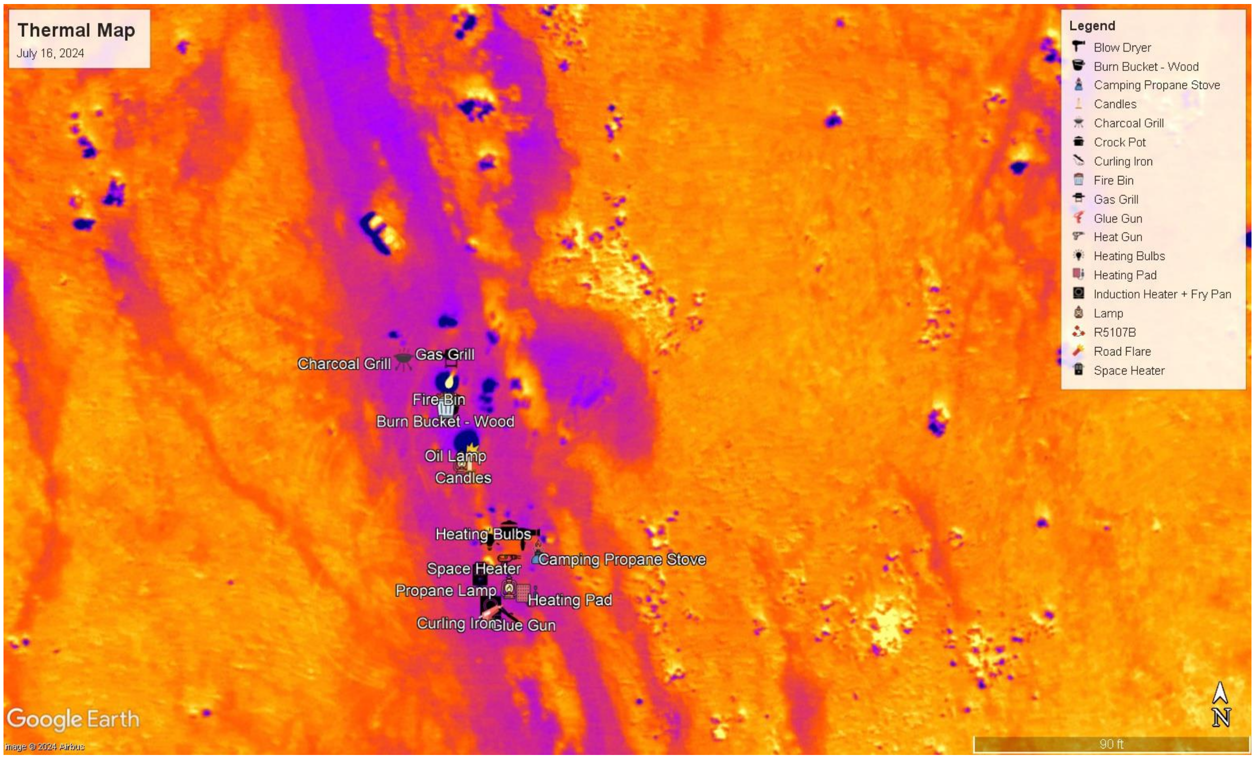



Figure 93. Mapping of GPS positions of heating elements on thermal map.

#### 2.29.2.3 Structure Fire Test – Completed August 7, 2024

A final round of flight testing was conducted in preparation for the prescribed burn exercise. The testing, documented in "A52 NMSU Prescribed Burn Structure Fire Test Report July 2024", built upon the previously conducted A52 Dry Run and Fire Testing. The research team implemented the products of previous related research and testing including sets of UAS, support functions, and products for this disaster. A defined set of expected operational elements was outlined in this test before the prescribed burn.

The Structure Fire testing was conducted August 7, 2024, at the Las Cruces Fire Department Fire Training Facility at the Las Cruces International Airport. The flights were coordinated with the airport to take place over the airport property. The team set up at two locations near the buildings. Figure 94 show the flight location. The goal here was to exercise a few specific elements before the required full event demonstration and to capture any specific and general cautions and improvements to the support. The main foci derived from the test objectives were to 1) re-test some of the flight systems, sensors, equipment, and procedures in a simulated mission scenario that had issues during the previous two tests; 2) collect lessons learned; and 3) assess post processing of the data products. The mission practiced selected elements required before supporting a prescribed burn. The Structure Fire Test objectives are outlined below:

The primary test objectives were:

1. Provide flight overwatch through mission.
2. Provide real time visuals (operator directed) of event.
3. Provide mapping of smoke obscuration.
4. Provide guidance and lessons learned from flight operations.

Secondary test objectives were:

1. Assessment of the data products and quality.
2. Assess positioning and other safety and performance metrics.

Figure 94. Las Cruces Fire Department fire training building.

The Structure Fire Test was executed exactly as planned and detailed in the FAA approved Test Plan and Test Cards with eight flights during the test day. The flights included a tethered overwatch UAS with a thermal and electro optical camera, a free-flight multi-copter with a LiDAR sensor, and a small multi-copter to capture images and video. All of the desired fights and system checks were completed. There were challenges with generating thick smoke during the initial part of the testing. An adjustment was made with the Fire Fighters real time to do a second burn at their flashover testing facility. This produced significantly more smoke for the testing. All flight systems worked as desired. Lessons learned focused on equipment operation, system redundancy, safety, LiDAR imaging limitations/planning, and LiDAR image post processing.

Post flight data products were produced. Some of these are presented below with a few additional selected images from the test. Figure 20 shows the back view of the fires test building. Figure 95 shows the tethered overwatch UAS in the air above the buildings. In this image, the X6 with the LiDAR is on the pavement near the center of the image. The multistory building on the right is where the fire was lit, just inside window numbered #3. The red structure that looks like a train caboose in the left side of the image is the flashover test building.

Figures 96 is an example of an image capture from the tethered UAS. It clearly shows the burn barrel inside the window, the vent duct heating where the smoke is exhausted. It should be noted that the elements inside the building are not visible from the outside, and the thermal imagery makes these clear. The smoke from the window was not observed via the thermal camera. Although could be seen through the EO camera. This is likely due to the limited amount of smoke that could be produced inside of this room. The visibility of the smoke is enhanced by the diffraction of light through gasses of different densities (Schlieren lines).

Figure 97 shows the fire and smoke coming out of the flashover training facility. Figure 98 shows the tethered view of the facility during the test. During flashover training, the Fire Fighters enter the building on the left and the flames burn along the ceiling in the area shown where the temperature is noted as +225.9°C. The heat pattern shown is exactly what we were told it would be. The amount of smoke obscuration from the thermal camera is very limited to the area the smoke is being released from. This obscuration appears to be amplified by the heat of the smoke observed by the smoke matching the color of the door on the right side of the flashover chamber.

One goal of this testing was to fly the LiDAR aircraft over smoke to assess how well the system can record data (Figure 99). The smoke generated during the operations was not dense billowing smoke. During flight, the UAS with the LiDAR was constantly moving over the flight area collecting data. Unfortunately, during the structure fire we were not able to create enough smoke to definitively determine if smoke will degrade the performance of the LiDAR. Not enough billowing thick smoke was being generated during the flights. For structure and small fires, the small amounts of smoke during the burns, was not enough to create any adverse effects to the functionality of the LiDAR scanner. For this testing, there was no impact on sensor performance.

Figures 100 and 101 show two captures of the LiDAR mapping of test area. It should be noted that the produced LiDAR images are 3D models that can be manipulated to any desired view. These are only two selected imaged from a full 3D model. One highlight from these two images and the LiDAR product is that the vertical side walls of the tallest structure are not captured well. They could be described as “pixelated” in appearance or appear to be missing. This is a function of the UAS flight pattern, distance between legs of the aircraft runs, and the challenges with imaging vertical surfaces from above. There were also some artifacts or ghosting in some of the LiDAR images due to back-to-back flights. There are ways to enhance the capture of these features through mission planning and system resets. These were both lessons learned.

All of the fight missions were completed safely under Part 107 operations. There were no safety challenges, and there were only a few minor equipment challenges that were encountered. All of the items were captured in the lessons learned. All of the desired elements and system checks were completed. All of the primary and secondary objectives as outlined before the missions were met in advance of the planned prescribed burn exercise.

Figure 95. Back view of structure. UAS with LiDAR in the foreground.

Figure 96. Tether overwatch of buildings.

Figure 97. Burn in progress with heat coming out vent.

Figure 98. Fire in flashover trainer.

Figure 99. Fire and smoke generation.

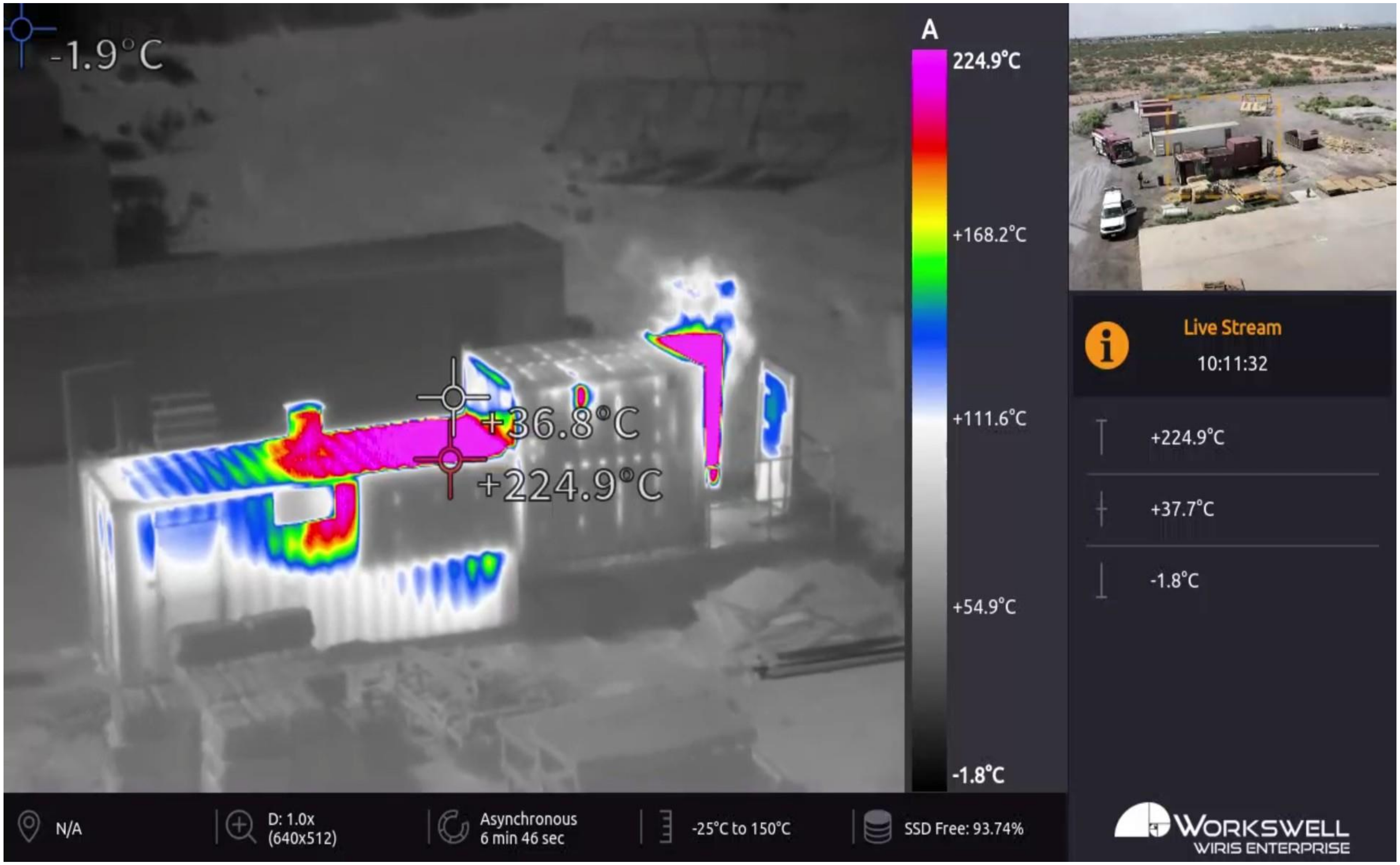



Figure 100. Tethered overwatch thermal view of flashover trainer.

Figure 101. LiDAR mapping of test area.


Figure 102. Additional view of LiDAR mapping of test area.

All of the above were in preparation for the test campaign conducted at a forest/burn area south of Pontotoc, Mississippi. The burn was originally planned for a location in New Mexico, but with the extreme fire season in New Mexico and the delays in receiving the support equipment from vendors, the window for a prescribed burn in NM was not available. The team worked with personnel at RASPET (Raspet Flight Research Lab) and MSU to identify an alternate location. The MSU team coordinated with NMSU and Mr. J.P. Cromwell, the Area 12 Forester and Associate Wildlife Biologist® with the Mississippi Forestry Commission in Tupelo, MS to identify a tract that he was preparing to treat and subsequently burn.

The shape files for the burn location were provided to the team and the associated Test Plan and Test Cards were prepared. The logistics to coordinate personnel and equipment from multiple locations across the US was complex to ensure all key personnel and resources were available at the designated time. The key focus for support centered on the potential burn windows from the Forester and on NMSU and UAF for the mission support personnel, UAS, and the support equipment needed for remote operations in a different part of the country. Both of these team identified all of the equipment needed. These packing lists were refined through the three rounds of staging tests noted above.

Logistically, it is difficult, expensive, and time consuming to ship batteries to and from Alaska. To assist the UAF team, the NMSU team provided batteries for one of their aircraft so they did not have to ship. Additional support equipment like gas cans and tool boxes were packed by the NMSU team to support the UAF operations. All of the equipment was packed over a several week period in preparation for the three-day drive of the truck and trailer in advance to prepare for the pre-mapping and burn day operations. The balance of the personnel traveled by air to Memphis, TN to attend the operations. All of the advanced approvals and local logistics were coordinated in advance of the operations to ensure no delays.

### *2.29.3 Wildland Fire: Controlled Burn Functional Exercise Execution*

The controlled burn functional exercise took place over a four-day period September 2 to 5, 2024. The testing, documented in “A52 NMSU Prescribed Burn Test Report September 2024”, built upon the previously conducted A52 Dry Run Testing, Fire Testing, and Structure Fire Test. The research team implemented the products of previous related research and testing including sets of UAS, support functions, and products for this disaster. As with all the other precursor tests, there were defined sets of expected operational elements outlined before the prescribed burn.

The prescribed burn location was originally planned in either New Mexico or Arizona. Spring of 2024 was very difficult fire season that included the burning of hundreds of structures in and around Ruidoso, NM in the South Fork Fire and Salt Fire in southern New Mexico. It was clear that the A52 team would need to look for another location for the prescribed burn. MSU personnel put the team in contact with the Mississippi Forestry Commission. They identified a 121-acre plot that had been prepared to be burned. The A52 focused on the logistics and coordination to attend this burn.

The area identified by the Forestry Commission was south of Pontotoc, Mississippi. The land had been logged approximately 1.5 years ago. All the quality trees were removed for lumber and this left scrub underbrush plus a number of standing trees on the property that were of no commercial value. In late July the area was treated from an airplane to prepare for the burn. Much of the material on the ground was dead, very dry, had some initial green growth, or were standing trees. There were both wood and brush piles on the property that had been pushed by the logging team.

Mississippi provides a cost share program for the Mississippi Forestry Commission to do these burns. The landowner gets some financial support to reclaim these areas after commercial logging. Weeks ago, the forestry team cut margins around the edges using bull dozers to make fire breaks. This was done along the entire planned burn perimeter. Post burn, this area will be reclaimed and a new pine forest will be replanted by hand. The tract will be ready for harvest in ~35 years from now.

Figure 103 is the shape file provided to the A52 team for the planned burn area. One can see that the area is somewhat divided into three separate sections. The areas are a small 10-to-11-acre plot north of Williams Road; a large area south of Williams Road, West of Redland Road; and north of an old historic late 1800’s homestead that was not be burned; and the largest southern section of the property. The team referred to these areas as the North, Middle, and South sections. UAS flights were generally set up to cover these areas separately because of the size of the burn area. Note that these Google Earth images are older and show full stands of pine trees that were no longer present on the property after the logging operations.

Figure 104 has an overlay of the approximate North, Middle, and South sections. The small ~10 acre section is north of the road. The large cutout area in the middle of the larger section is a historic homestead where the owner did not want burned. This general location was considered the dividing line between the middle and south sections. Because of the tree lines between these sections, there was a requirement to place VOs with radio communications at key locations, many time on the other side of a tree line to ensure flight safety. The staging/launch locations for the operations on the mapping days were just to the west of the north/south road and approximately centered north and south on the target areas. The three main launch/recovery areas are marked with an asterisk (*) in the figure. On the burn day, all flights were from near the cemetery. It should be noted that the entire area was mapped before the burn. The final burn on Wednesday only included the North and Middle sections. The Forester told the team before that this was the largest tract of land they had tried to burn in one day, and in the end, they were only able to safely control the fire in two of the three areas and made a decision to not burn the South section until a future time.

Figure 103. Shape file provided of the planned prescribed burn area.


Figure 104. North, Middle, and South sections of the prescribed burn area with launch locations (*) shown.

The team set up at multiple locations around the property to safely fly the pre, during, and post missions. In addition to the marked locations, the sUAS were flown from multiple local locations as needs arise. The goal here was to fully exercise all of the define elements required in this full event demonstration and to capture any specific and general cautions and improvements to the support. The main foci derived from the test objectives were to 1) exercise the flight systems, sensors, equipment, and procedures in the actual mission scenario; 2) collect lessons learned; and 3) assess post processing of the data products. The mission practiced all of the elements required to support this controlled burn functional exercise. The Controlled Burn Test objectives are outlined below:

The primary test objectives are:

1. Provide flight overwatch throughout the entire burn operation.
2. Provide real time visuals (operated directed) of event.
3. Provide pre and post mapping of event location.
4. Provide guidance and lessons learned from flight operations.

Secondary test objectives are:

1. Assessment of the data products and quality/resolution of the produced composite images.

2. Assess positioning and other safety and performance metrics.

The desire to understand the potential amount of fuel in an area is of great interest to fire researchers, resource managers, and foresters. The mapping of these areas in advance was highlighted during the discussions with the local forester during this prescribed burn. As the lead for the actual burn itself, he noted that he needs as much information as possible in advance of the actual burn. This includes accurate maps and if possible, spatially-explicit forest structure information. This is required to support a safe burn operation. From an analytical standpoint, having this information can allow for the development of forest fire behavior models. The development of these fire models for this prescribed burn was beyond the scope of this specific research effort, but the demonstration of the collection of data to support these model developments was part of the research.

There are multiple approaches to gathering this information. “In particular, reliable estimates of several critical forest canopy structure metrics, including canopy bulk density, canopy height, canopy fuel weight, and canopy base height, are required to accurately map the spatial distribution of canopy fuels and model fire behavior over the landscape. The use of airborne laser scanning (LiDAR), a high-resolution active remote sensing technology, provides for accurate and efficient measurement of three-dimensional forest structure over extensive areas.” (Anderson). LiDAR is not the only way to make fuel load estimates. Traditional EO images can be used (Sunjoo) by generating object-based images and 3D-model red/green/blue band characteristics to estimate fuel loads. Stereovision (visible and infrared) can be used to produce 3D georeferenced models that can be used to assess the plane that the fire is spreading on, as well as direction and speed of the spread (Ciullo). This approach uses fire color segmentation algorithms to identify different parts of the flame and determine which parts of the fire are most critical or dangerous. AI models to identify fire load types (oil, petroleum products, petroleum gas, and vegetation) using data from a high-res camera on board a UAS (Vytovtov). This means that the type of fire could be determined in real-time, eliminating the need to process the data off-site.

Again, there are multiple approaches that can be used before a fire to map and make estimates of key parameters like canopy bulk density, canopy height, canopy fuel weight, and canopy base height. These are done with the goal to have an accurate map the spatial distribution of canopy fuels and model fire behavior over the landscape. The raw data can be collected with LiDAR and EO sensors. These same tools can then be used post burn to assess the effectiveness of the burn and for comparison. One goal in this prescribed burn was the data collection elements pre and post fire that could be used by a fire researcher, resource managers, or forester and not to actually do the calculations.

The Prescribed Burn Test was executed as planned and detailed in the FAA approved Test Plan and Test Cards with 51 UAS flights over the four testing days. The flights included many mapping flights, a tethered overwatch UAS with a thermal and electro optical camera, overwatch from a UAS at ~1,100 ft AGL, a free-flight multi-copter with a LiDAR sensor, an aircraft that could be flown to look at desired locations with a thermal and EO cameras that was used for both mapping and spot checks, and a small multi-copter to capture images and video. Detailed breakdowns of the day-by-day operations, images/video captured, and produced maps/data products are included in the full Prescribed Burn Test Report. In advance of the flight operations week, the NMSU truck and trailer left Las Cruces on Friday August 30, and arrived on Sunday morning. This included all of the UAS and support equipment needed for the operations except the UAF aircraft which they checked as luggage on their flights. The NMSU and UAF teams arrived in Mississippi on Sunday. There was a delay in the UAF team receiving the Super Volo, but it was delivered to their hotel on Monday morning. Short day by day summaries of the operations, flights, and examples of the products are presented below.

Monday Sept. 2, 2024 (Labor Day)

Monday was spent with initial field assessment, integration, flight tuning, and the first mapping flights. The significant size of the property required a survey of multiple launch/recovery areas. Three different launch/recovery locations were used during the day to make sure flights were LOS and mapped the proper areas. NMSU performed tuning flights on both the Large X-6 and the Small X-6. Minor adjustment to settings on one aircraft for local operation. Both aircrafts were deemed flight ready. The Trinity aircraft had an issue with a software update that would not allow connection to any of the sensors, showing all memory cards as being full (they were not), and other issues. The aircraft was packed up and taken back to the hotel at the end of the day to address the issue. The fix was to back date to older previous software version that allowed the Sony EO camera, LiDAR, and Altum camera to work properly.

The Matrice was flown with no issues over the burn area. The Super Volo camera was integrated and operational. There were some minor issues with the connection to the controller which was swapped out and then performed perfectly. Its flight over test area had no issues. Post tuning flights, the X-6 with the LiDAR was flown on 4 mapping missions which mapped the entire burn area completing this required pre-burn element. The Skydio was flown to take pre-burn images and video of the area. There were no flight or safety related issues or concerns. A summary of the flights for the day is as follows:

- Flights: 11 total (2:38 flight time total)
    - Large X-6 – 1 tuning flight, 4 LiDAR mapping flights (1:00 flight time total)
    - Small X-6 – 2 tuning flights (0:08 flight time total)
    - Super Volo – 1 flight (0:38 flight time total)
    - Matrice – 1 flight (0:22 flight time total)
    - Skydio – 2 flights (0:30 flight time total)

Figure 105 shows various images of the area prepared for the prescribed burn. The quality timber has been removed, and there are still some standing trees. The other vegetation has been dried thought chemical spraying. The logger piled some timber and the burn team bull dozed margins around the entire area. Figure 106 is a UAS view of a portion of the prepared burn area. Various UAS used for the flight operations mapping and mission support are shown in Figure 107.

Operations followed previous protocols with no issues. There were two lessons learned. First, having backup systems (ex. Super Volo controller) on hand allowed for a quick swap out to ensure flight operations. Second, system updates immediately before operations should be avoided, if possible, when all systems previously functioned properly (ex. Trinity system update) and there are potential impacts to functionality of the equipment. These updates should be planned in advance with testing to ensure operation, or if pushed by the manufacturer, the team should be prepared, if possible, to revert to the older version that worked.

Figure 105. Various images of the area prepared for the prescribed burn.

Figure 106. UAS view of a portion of the prepared burn area.


Figure 107. Various UAS used for the flight operations mapping and support.

*Tuesday Sept. 3, 2024*

Tuesday was set for final aircraft tuning and mapping flights with the Matrice and Trinity aircraft. Additional personnel from Oregon State University, North Carolina State University, and MSU were on site with the focus on some local coordination and collection of Lessons Learned. Flights were from two of the locations used on Monday. The UAF team performed two mapping flights with the Matrice and completed two flights with the Super Volo to address some connection/range questions. With the NMSU Trinity issues resolved, all of the required pre-burn mapping flights were completed with multiple flights of the Altum multi-spec, EO, and LiDAR sensors. There were minor issues with overheating on avionics late in the day, but the systems were cooled and flights completed. The small X-6 was also prepared for tethered operations on Wednesday. At the end of the day, all pre-burn mapping missions were complete and all systems and flight systems were ready for the Wednesday burn operations. Again, there were no flight or safety related issues or concerns. A summary of the flights for the day is as follows:

- Flights: 11 total (4:32 flight time total)
  - Trinity EO – 3 flights (0:51 flight time total)
  - Trinity LiDAR – 2 flights (0:32 flight time total)
  - Trinity Multi-spec – 2 flights (0:49 flight time total)
  - Super Volo – 2 flights (1:46 flight time total)
  - Matrice – 2 flights (one EO and one thermal) (0:34 flight time total)

All of the mapping flights require multiple images of data to be combined into composite images of the area. One EO composite image (Figure 108) stitched from the Trinity UAS captured images is of the entire burn area before it has been burned.

There were a few Lessons Learned focused on operational items related to shade and flight prep, and minor improvements, but no items germane to other potential prescribed burns. Again, all NMSU and UAF systems were deemed ready for flight operations.

Figure 108. Composite image stitched from UAS captured images of the entire burn area before the burn.

Wednesday Sept. 4, 2024

Wednesday was the prescribed burn day, the functional exercise that had been well over a year in planning. The entire focus of this day was UAS support flights. The research team to meet at the Redland Cemetery at 8 AM with burn team showing between 8:30 and 9 AM. Personnel from the FAA, UAH, and MSU joined the numbers. The MSU attendee focused on taking photos and video of the people, day, and activities.

The fire team prepped the areas first with heavy equipment and then started the burn late morning. The research team's efforts were on a non-interference basis. The baseline flights were overwatch with Super Volo, overwatch with tethered X-6, and Matrice for spot viewing. Additional flights of Skydio for images and video, and large X-6 with LiDAR to assess imaging through smoke were completed.

Per the burn team’s request, all flights were from only one location. With the burn, the logical base of operations was set up in front of the Redland Cemetery. Almost all flights took off from this location. A few Skydio flights were from locations slightly down the road by the fire. This basecamp had separate areas set up for the Super Volo, tethered operations, Matrice, and flight management/control. All were within visual range of each other and team had radio communications with all locations.

The Forester preferred that the team not drive down to the other burn sites for safety reasons. The multitude of UAF Matrice flights focused on looking at hot spots and being directed by the burn team. With a rotating stock of batteries, the pilot was able to back-to-back multiple times. Fatigue was not an issue and these flights were excellent operations with tremendous interface and feedback from the Forester and burn team. NMSU provided VOs for these operations all day. It should be noted that some of these flights were Part 107 and some were under the UAF COA that allowed for operations higher altitudes. Some were 400 to 600 ft AGL because this provided better views to the Forester. The flights with the Super Volo were excellent overwatch with EO and IR. Flight control electronics did get very hot late in the day and caused connection issues. Again, these provided discussion points with the Forester and burn team real time.

The NMSU small X-6 on a tether provided visual and IR images. There were some camera connection issues and operation was not 100% of the time but showed capabilities. The range and zoom of the system were impressive. One of the desired success criteria was to fly the X-6 with LiDAR to assess how well LiDAR could see through smoke. There was a lot of smoke, and the resulting images were excellent with only a few artifacts that were incorrect points. The Skydio was flown three time to provide video and images of the burn. One flight was asked by burn team to follow one of the dozers on site (for imaging and for SA), but the aircraft was buffeted by the thermals from the fire and the task was not possible without potential damage to the aircraft. The smoke also obscured the VO from seeing the aircraft and the mission was safely aborted and ended.

The on-site FAA representative, Bhanu Kota asked questions and provided constructive input all day long. This was helpful to ensure the team was meeting the comprehensive success criteria. Patterson Hilaire, a MS Forester with the Mississippi Forestry Commission, was on-site as an observer for the day. He interfaced with the team all day long to give an independent view of the operations in a role that did not impact the burn team. He provided very valuable inputs all day long through observing all of our operations. The burn boss, JP Cromwell (also with the

Mississippi Forestry Commission) periodically checked in with our team during the day. He also provided significant inputs. The foresters asked for UAS views on the controllers to chase bull dozers, identify fire jumping the line, identification of personnel, and many pinpoint views desired by the Burn Team.

All required success criteria and all the desired success criteria were met with this operation. There were also a few additional bonus efforts completed during the operations. On a day with a very hot fire, smoke, and ash in the sky, there were again no flight or safety related issues or concerns. A summary of the flights for the day is as follows:

- Flights: 20 total (5:52 flight time total)
  - Super Volo – 3 flights (0:41 flight time total)
  - Matrice – 9 flights (3:35 flight time total)
  - Tethered X-6 – 3 flights (0:40 flight time total)
  - X-6 with LiDAR – 2 flights (0:15 flight time total)
  - Skydio – 3 flights (0:41 flight time total)

Figures 109 to 114 capture a few images from the burn day including UAS operations, fires, fire management, and fire support personnel working with the UAS research team. Figure 114 shows the view of the burn area from the tethered UAS. A thermal image of the burn area from the tethered UAS shows the EO image, thermal image and the temperature scale. The Super Volo provided excellent vies of very wide areas of the burn operation (Figure 116). Spot checks of one portion of the burn area from the Skydio are shown in Figure 117.


Figure 109. UAS operation on burn day.

Figure 110. Part of the burn pile lit up.

Figure 111. Mississippi Forestry Commission’s JP Cromwell managing the burn.

Figure 112. Firefighter Justin and Patterson Hilaire working with UAF’s James Coppell who is flying the Matrice.

Figure 113. The heat from the fire was quite intense even 100’s of feet away.

Figure 114. Tethered UAS view of the burn area.

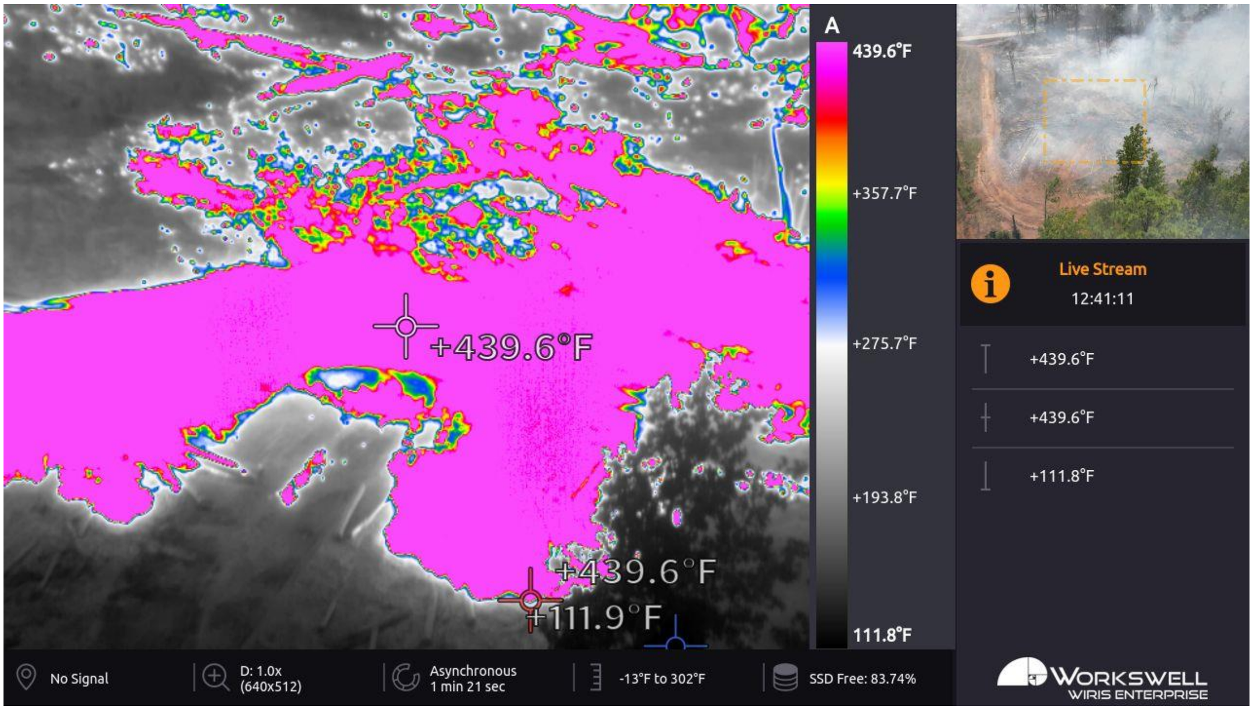



Figure 115. Thermal image of the burn area from the tethered UAS.


Figure 116. View of the downrange area from the Super Volo.

Figure 117. Skydio view of one portion of the burn area.

There were several minor operational/best practice related items from these operations. One was the pilot assessing real time to end one flight early as he noticed that the aircraft was being buffeted by thermals from the burn and the VO lost visual in the smoke. The controller temp for 900 MHZ got too hot to touch and had drop outs. The UAF team has likely established the full operating limits for this from previous very cold weather flights and these hot weather flights. Most importantly, multiple inputs from Burn Team and Forester that gave insight into possibly best/better practices and desired information during burn.

Thursday Sept. 5, 2024

Thursday was focused on multiple remapping flights post burn for pre/post burn comparison. This included EO, IR, and LiDAR flights. The post burn UAS mapping flights and video/picture collection flights were completed. After the flights, the systems were packed for shipping. Assessment of the burn area on Thursday morning was interesting. There were many smoke plumes across the landscape as well as places that still had active flames. The areas smoked all day. While the team had previously flown and mapped all 121 acres, due to the dryness (they have not had rain in over 9 weeks) and the winds on Wednesday, the Fire Team decided to only burn the North and Middle sections of the property. The southern section was not burned at all and will be burned in the future. The team was told that the burn was a challenge during the day due to the dryness and winds. The fire did jump across the road in sections which kept the fire team very busy. The burn team consisted of JP as lead and another 5 personnel working the fire.

All of the UAS mapping flights were from one location, the middle section of the property. Since the southern section was not burned, no post burn mapping flights were flown over this area. A couple of video and picture flights were flown from both north and south of the burn area. The UAF team completed to flights with the Matrice for post mapping. Again, these were at 500 and 600ft under their class G COA. The Super Volo and rest of the UAF equipment was prepared for shipping and packed up. The NMSU team flew the X-6 with LiDAR twice to re-map the center and north sections. The Trinity was flown 3 times to map (EO, thermal, and LiDAR) over the middle and north sections. The Skydio was flown two times to provide video and images of the burn. There were no flight or safety related issues or concerns. A summary of the flights for the day is as follows:

- Flights: 9 total (2:26 flight time total)
    - Matrice – 2 flights (0:31 flight time total)
    - Trinity EO – 1 flight (0:18 flight time total)
    - Trinity LiDAR – 1 flight (0:15 flight time total)
    - Trinity Multi-spec – 1 flight (0:21 flight time total)
    - X-6 with Lidar – 2 flights (0:21 flight time total)
    - Skydio – 2 flights (0:40 flight time total)

Figure 118 shows the post burn landscape ~20 hours after the burn. Figure 119 presents another view showing multiple smoke plumes and small fires still burning the day after the fire. LiDAR mapping post burn (Figure 120) was completed with a post burn LiDAR composite of the north section shown in Figure 121. The Altum thermal composite image from the day after the burn shows many active hot spots (Figure 122). The effectiveness of the burn is show by looking across a wide section of the burn area from a height with the Skydio (Figure 123).

Figure 118. Post burn landscape ~20 hours after the burn.

Figure 119. Multiple smoke plumes and small fires still burning the day after the fire.


Figure 120. LiDAR mapping post burn.

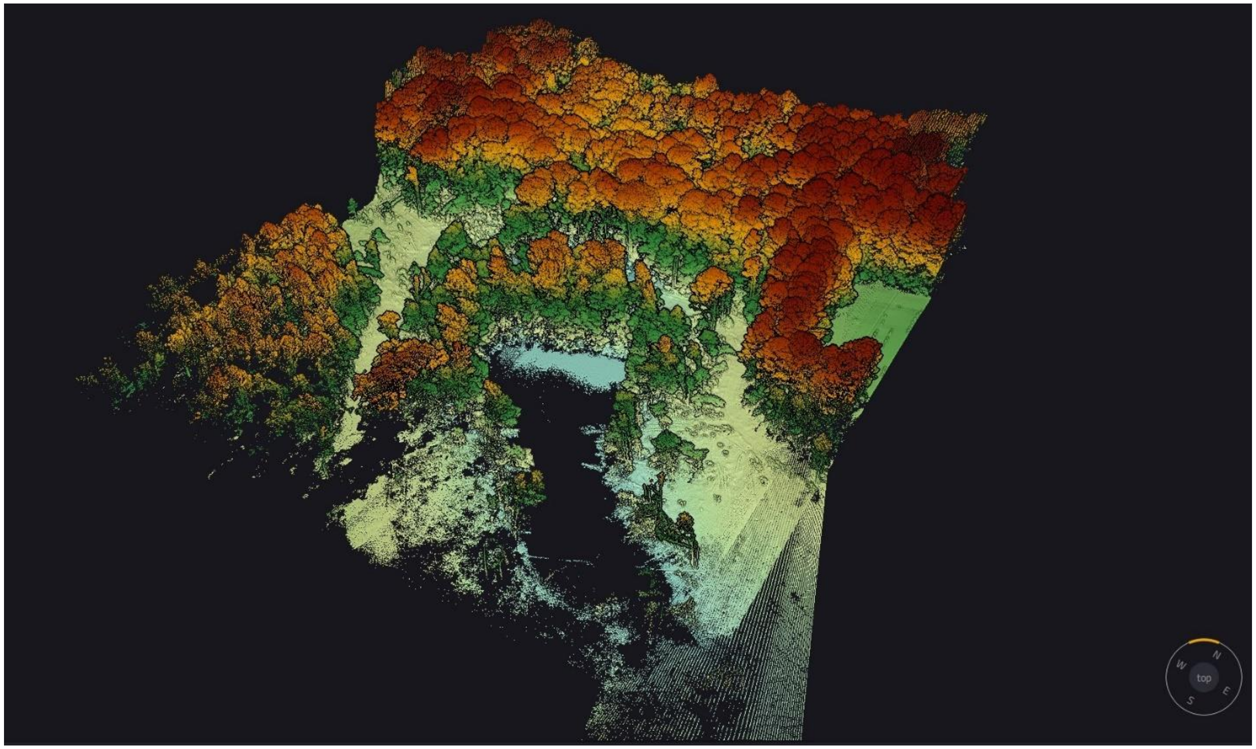



Figure 121. Post burn LiDAR composite of the north section.

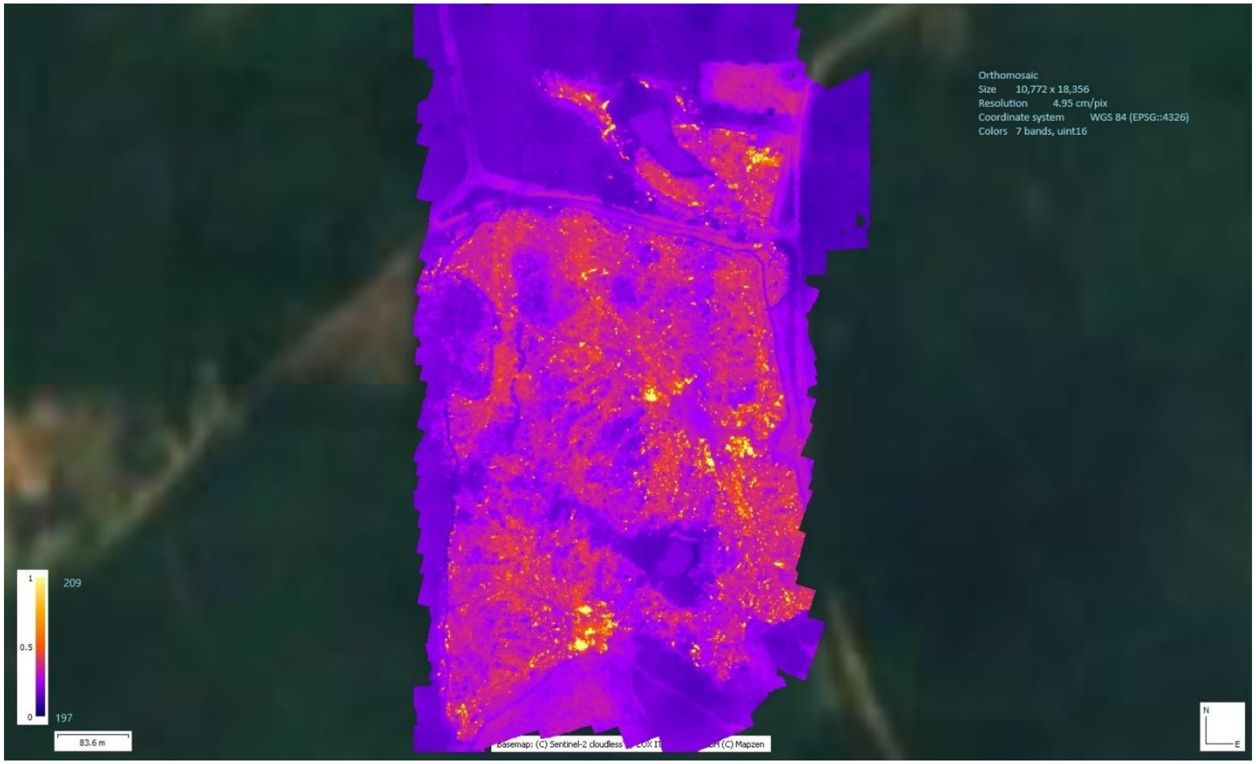



Figure 122. Altum thermal composite image the day after the burn showing many active hot spots.

Figure 123. Looking across a wide section of the burn area from the Skydio.

The team had an informal feedback session with JP as the NMSU equipment was packed up and readied for the drive back to NM. Summarizing the Mississippi Forestry Commission feedback from JP and Patterson included;

- Patterson provided very valuable inputs all day long by observing all of our operations directing views and running operational scenarios real time.
- JP focused on the support for having the "eye in the sky" where he could direct it to specific locations was invaluable. He only had 5 on his team (usually have six or more), and while they were working one section, the fire jumped across the road well away from the team. He was able to redirect the team real time to the exact locations for each jump.
- The team was also able to provide visuals at a jump near the cemetery location. This allowed a very proactive response.

All the daily mission required and desired success criteria were fulfilled on Thursday. The data processing, image rendering, and reporting is ongoing and included in the full Prescribed Burn Test Report. The planning flow from A28 that defined all of the UAS support functions, through two years of planning in A52, and all four incremental evolutionary flight-testing steps to this prescribed burn have now been operationally completed.

All of the fight missions were completed safely with most under Part 107 operations. As noted above, the Super Volo flights were at higher altitudes up to ~1,100ft AGL, and the Matrice was also flown up to 600ft AGL under the UAF COA. There were no safety challenges or issues. There were a few minor equipment challenges that were encountered. All of the items were captured in the lessons learned. There are always potential improvements to the processes and operations. Many lessons learned are germane to a team, a tweak to the procedures, or unique to a specific operation. Both NMSU and UAF A52 teams captured these lessons learned or reinforced some their best practices. There were a few global lessons learned that are more applicable post mission. The key ones are worth repeating here since some point toward bigger picture elements for future support of flight operations related to prescribed burns. These key notes are broken down by aircraft or required support function.

- Mapping products can take time post flight so the EO, thermal, and LiDAR images are generally not available immediately after a flight. Some processing and stitching time for the images can take many hours. Many of the Trinity maps are between 2.5 and 4.5 cm per pixel which is excellent resolution for the forester's applications (much much better than they currently have access to)
- Local weather may not provide full insight into the local wind conditions. And example of this was demonstrated when the Trinity fixed wing aircraft took off. As it goes up and before transitioning from vertical to forward flight, it "weathervanes" to the local wind direction. In one case the winds aloft were at least 90 degrees out of alignment with the ground winds. As a side note, the UAF team noted this wind direction difference and adjusted their takeoff direction with the Super Volo.
- Ambient temperatures can cause issues with some systems. While the operational temperatures were within manufacturer specifications, some items (ex. Super Volo controller) did heat significantly and cause some operational issues. This can be addressed by planning when items

may be exposed to temperature extremes and/or through real time mitigation (ex. adding cooling packs on equipment)

- There are multiple potential limits on the operation of equipment near the active fires. This can include the obvious exposure to high temperatures. During the active fire, the Skydio was attempting to follow a bulldozer movement at the request of the forester, and the aircraft was buffeted by thermals generated by the fire. At one point the smoke obscured the visual observation of the aircraft and the flight was immediately canceled and the aircraft was safely landed. This points toward specific operational protocols to enhance safety.
- The Matrice EO and thermal images were invaluable during the operations. These helped the burn team make real time decisions on resources and response. It should be noted that operation of the Matrice below 400ft AGL was not near as effective as operation of the aircraft at 500ft to 600ft AGL. While the team had all of the proper approvals to legally and safely do this, these flight altitudes are not possible under Part 107 flights.
- The Super Volo also flew at much higher altitudes than the Part 107 limits. This aircraft can provide excellent wide area oversite coverage for many hours flying at 1,100ft AGL with a camera that can be commanded on a target with excellent zoom and resolution. It more than adequately covered the entire burn area for this event. The coverage area can be adjusted real time to shift the focus of the targets. It does require a team of at least two people to operate, it is an expensive asset, and requires something more than Part 107 approvals.
- The tethered X-6 also requires a team of two people to operate. The visibility range for overwatch is obviously more limited than the Super Volo. For limited area events, this provided excellent EO and thermal coverage over a good portion of the burn area. It cannot be packed and moved easily if target areas change.
- There was a question of how well the LiDAR would work with significant smoke present. While there is more processing to be completed and additional assessment of the products, the smoke on this fire, which was heavy at times, did appear to slightly impact the results. There were some artifacts that were in the air above the ground which are not real points, but overall, the LiDAR still performed excellent imaging even with smoke present.

In summary, all of the desired elements were completed. All of the primary and secondary objectives as outlined before the missions were nearly completely met during this prescribed burn exercise.

#### *2.29.4 Wildland Fire: Controlled Burn Functional Exercise Follow-Up Activities, If Applicable*

There were no specific follow up activities required to fulfill the original set of requirements; however, there were some additional post processing of composite images and analysis completed. These can be found on an addendum/revised version of the document, “A52 NMSU Prescribed Burn Test Report September 2024.”

Unlike many of these functional exercises, the UAS operations for a prescribed burn or any fire had to consider the flight space in 3D. Some disaster responses provide information on the two-dimensional challenge on the ground through an overhead perspective. Others require the delivery of elements from one place to another. Fires, radioactive plumes, volcanic plumes, and other similar disasters may present similar overhead and delivery challenges but have the added dimension of safely navigating the dynamic airspace that is actively being impacted by the event itself. In this case, the fires heat, turbulence, and smoke forced the operators to fly at different altitudes, or in modified flights to safely operate.

Potential follow up activities could include the development of operational protocols around fires for altitudes, standoff distances, etc. to ensure safe operations. Adjusted flight altitudes may be beyond Part 107 limits. Definition, development, and testing of onboard systems for UAS temperature and wind speeds and direction may provide UAS health status to improve operational safety. Additional assessment of smoke impacts on LiDAR flights may prove valuable. Finally, a potential follow-up activity could be the development of a set of desired mapping protocols or criteria that would support the resource managers and foresters. Areas can be effectively mapped pre and post events, but what quality and resolution are actually needed to support their functions to maintaining the health of the land.

#### *2.29.5 Wildland Fire: Controlled Burn Functional Exercise Lessons Learned*

The Lessons Learned from this exercise are addressed in a separate Lessons Learned document which is included as an appendix to this document (See section 8.7).

# 3 RISK ASSESSMENT AND MITIGATION

## 3.1 Common Risks

Based on the prior A28 results and newly collected case studies, the common risks can be categorized into four groups: adverse operating conditions, deterioration of external systems, human factors, and UAS technical issues. Each category of risks is described in Tables 3 to 6. For example, the risk titled "Collision into Terrain and Terrestrial Entities" under the "Adverse Operating Conditions Risk" category is described as follows: "This hazard would be caused by a collision with a structure or people. A structure is any item on the ground, both stationary (such as a building) or mobile (such as a vehicle). Those people who could lead to a collision with an unmanned system include the public and mission crew."

Table 3. Adverse Operating Conditions Risk Category.

| Risk Name | Risk Description |
|---|---|
| Collision into Terrain and Terrestrial Entities | This hazard would be caused by a collision with a structure or people. A structure is any item on the ground, both stationary (such as a building) or mobile (such as a vehicle). Those people who could lead to a collision with an unmanned system include the public and mission crew. |
| Mid-Air Collision | This hazard would result from participating or non-participating aircraft failing to comply with See-and-Avoid requirement, non-participating aircraft failing to monitor appropriate ATC frequency, and/or non-participating aircraft operating well below airway altitude. |
| Rapid Onset of Inclement Weather or Disaster Specific Weather | This hazard can be caused by a lack of or not current weather briefing and/or localized winds due to terrain. Additionally, disasters like Wildland Fires, Volcanic Eruptions, or Nuclear Dispersion can cause BVLOS operations or instrument flight rules conditions. |
| Unexpected Winds Aloft | This hazard can be a result of wind gusts and/or sustained winds exceeding UAS operating specifications. |

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|---|---|
| Tethered sUAS #1 is close to people and property. Could fly away from control | The tethered sUAS will be secured to the airport infrastructure and will be staying at a fixed altitude above the airport. It will be positioned close to people and property. The tether could break and therefore, the UAS would be in fly away mode. |
| sUAS #2 is mobile and pushing the limits of VLOS. VO may lose sight of UAS | Manually flown UAS will provide proximal observations of the event and flying under VLOS operations with a visual observer. The mission may require flying to the maximum extent of observers' view and as such would be close to flying outside VLOS. This would then mean that the flight crew does not have sight of UAS or the airspace around it. |
| sUAS #3 is performing a counterattack and is taken out of action | sUAS #3 is providing counter UAS support to the disaster response and may have to intercept hostile airborne assets. As a result, its operational capacity will be impacted, and it is then taken out of action and cannot provide the support. This will leave no airborne assets to support ground teams and provide counter UAS support. |
| sUAS #3 is performing delivery of supplies and the mechanism fails | sUAS #3 will have the capability to provide supplies to ground teams involved in the terrorism event. When the supplies are being delivered, the mechanism fails and as a result, the supplies cannot be delivered. This means that the supplies do not reach those in need and the aircraft is then unable to perform its duties. |
| Terrorism event continues beyond one day and fatigue occurring in flight crews. | All UAS will aim to support the ground teams as they respond to the terrorism events at the local airport. The timeframe of the events will be dependent on the scale of the terrorism attacks and the capacity of the operational teams to mitigate the events and stop the attacks. This may mean that they extend beyond one day that will lead to potential fatigue for the flight crews. This can then lead to tired personnel and potential mistakes being made. |
| Lack of timing precision between missions prevents data from being compared. | There will be one large UAS being flown for the ground support as well as three sUAS teams. Each will be acquiring imagery and videos of the events as well as recording their flight logs and GPS locations of their flights. To cross-compare the data feeds and evaluate the data, each of these systems needs to be time-synchronized. If not, the data will not be able to be compared which will prevent cross-analysis of the UAS data. |
| Severe Weather Conditions | This hazard is a result of atmospheric conditions that change so there is a no-go for flight operations. Possible effects are a stop in flight operations and an aircraft that must rapidly RTL or end flight and the team left waiting and unable to complete their mission. |
| sUAS are mobile and pushing the limits of VLOS. VO may lose sight of UAS. | Manually flown UAS will provide observations of an oil spill over land as well as water and flying under VLOS operations with a visual observer. The mission may require flying to the maximum extent of observers' view and as such would be close to flying outside VLOS. This would mean that the flight crew does not have sight of UAS or the airspace around it. |
| Lack of fuel in large UAS performing multiple missions | This hazard comes from the large UAS, that is performing two flights with stop over, having enough fuel/power to complete the flights and all operations needed for the removal of the supplies. Possible effects are the large UAS being unable to complete the two flights and having to return to the original take-off location. The lack of fuel could lead to loss of capability to control the UAS and a controlled or uncontrolled descent into terrain/terrestrial entities. |
| Eruption intensity dramatically changes while flight occurring | This hazard is a result of a rapid change in the volcanic activity that puts the Mt. Spurr summit team at risk. Possible effects are a need to evacuate the flight team and/or an aircraft that is at risk from the volcanic activity. |
| Ash/gas clouds move away from flight route for sUAS | This hazard is a result of the downwind clouds that need to be measured, moving, and dispersing away from sUAS and away from its pre-defined flight route. Possible effects are a flight route that cannot provide observations or runs out of power or would need to fly under BVLOS before collecting all the data. |

| | |
|---|---|
| Toxic ash and gases | This hazard can be caused by the wildland fire ash concentrations impact to the aircraft and visibility leads to IFR only conditions. Possible effects resulting from this hazard are a loss of aircraft performance and ability to continue the mission. |
| Ash/gas clouds move away from flight route | This hazard is a result of the downwind clouds that need to be measured moving and dispersed away or towards the sUAS and away from the pre-defined flight route. Possible effects are a flight route that cannot provide observations or runs out of power or would need to fly under VLOS before collecting all the data. |

Table 4. Deterioration of External Systems Risk Category.

| Risk Name | Risk Description |
|---|---|
| Generator Failure [on-board] | This hazard can be caused by engine component failure and/or rotor failure, depending on if large fixed-wing or small rotor UAS respectively. |
| Generator Failure [ground-based for GCS] | This hazard can be caused by a lack of power in the generator to support the GCS equipment when mains power is unavailable. It will impact other mission equipment that will need to operate on battery power until a backup generator power source is found. |
| Loss Function of Tracking Antenna | Causes include tracking antenna losses either its GPS position or the aircraft's, antenna becomes disconnected from Control Station subsystem, and/or antenna subsystem mechanical failure. |
| Loss of the GCS | This hazard could be caused by a computer reboot, loss of power, frozen screen, or cold conditions leading to GCS shutdown. |
| Large UAS is unable to stay airborne or takes too long to launch | This hazard comes from the time taken to get the large UAS airborne to collect data thus limiting observations of the event. It can be caused by a need to refuel and therefore no high-altitude observations of the response. Possible effects are no higher altitude data to see the full extent of the event and/or act as a communications hub. |
| Large UAS flies from National Airspace System to temporary airspace restriction zone. | Large UAS will start at a nearby airport and fly into US NAS and the specific airspace at and surrounding this airport. It will then fly from the NAS, where there could be other crewed and uncrewed systems, into TFR setup over the terrorism event at Huntsville airport. Flight team does not have permissions setup with the operations center and therefore will be unable to enter TFR. |
| Large UAS needs refueling and loose higher altitude observations | The Large UAS supporting the operations is unable to stay airborne for the full extent of the terrorism event and it needs to return to the landing airport for refueling. This will remove the higher altitude observations of the events to support the ground operations and so the decision support system will not be able to view the full extent of the airport and the impact of the events. |
| Lack of safe landing for flight operations over water | This hazard comes from a sUAS flying over water and the crew undefining a safe landing zone and/or being unable to perform a manual landing back on the boat. Possible effects are the sUAS having to ditch into the water as it does not have a safe landing site or fails to land back onto the boat. |
| Lack of safe landing for sUAS #1 flight operations over water | This hazard comes from a sUAS flying over the Port of Valdez and the surrounding bay and crew undefining a safe landing zone and/or being unable to perform a manual landing back on the boat. Possible effects are the sUAS having to ditch into the water as it does not have a safe landing site or fails to land back onto the boat. |
| Toxic ash and gasses concentrations along flight routes | This hazard caused by an oil spill fire concentrations impacting the aircraft and visibility leads to IFR only conditions. Possible effects resulting from this hazard are a loss of aircraft performance and ability to continue the mission. |

Table 5. Human Factors Risk Category.

| Risk Name | Risk Description |
|---|---|
| Physiological Human Factors Event | This hazard would result from a loss of situational awareness, crew miscommunication, and crew fatigue. |
| Loss of Communications Between Crew Members | This hazard results from communications equipment failure, insufficient battery power, and/or radio interference from an external source. |
| Loss of Communications Between Flight Crew and ATC | This hazard would result from communications equipment failure, insufficient battery power, and/or radio interference from an external source. |
| Non-crew Member Interruption of Flight Crew | Causes for this hazard occurring and impacting operations include spectators watching the mission asking questions or getting too close to the crew members who are performing the mission. |
| Crew unable to provide visual observations for sUAS flight | This hazard comes from a required flight time of the sUAS missions extending beyond the visual observation capabilities of the crew and there is no BVLOS plan in place. Possible effects are that a mission has to end and cannot support operations or a sUAS cannot be tracked and so a RTB is required to ensure the crew can keep a visual on it and airspace. |
| Crew unable to ensure safe operations over people and/or property | This hazard comes from the flight crew being unable to ensure safe flight operations when there are people and/or property below the flight route. Possible effects are a crash of the UAS with people/property or a need to RTB because the PIC cannot ensure safe flight operations. |
| sUAS flight crew unable to ensure safe operations over people and/or property | This hazard comes from the flight crew being unable to ensure safe flight operations when there are people and/or property below the flight route including those in the City of Valdez, the Oil Terminal, and emergency response ground teams. Possible effects are a crash of the UAS with people/property or a need to RTB because the PIC cannot ensure safe flight operations. |
| Loss of communications between crew at two GCS | This hazard comes from two flight crews and two GCS used for the UAS operations and a drop in communications between them when based in different locations. Possible effects are a drop in GCS tracking of the UAS and/or no confirmation of the handing of the UAS from one GCS to another. |
| Ground team unable to access payload bay of large UAS | This hazard comes from the ground crew at the second site being unable to offload the supplies and/or unable to access the payload bay. Possible effects are a failure to drop off the supplies at the needed location and/or a return to the original take-off site within completing the mission. |
| Loss of capability for one of two GCS used in mission | This hazard comes from an aircraft loss of control between two GCS and only one of the GCS can track the UAS. Possible effects are an uncontrolled aircraft that is unable to be tracked in the NAS or an aircraft that is unable to reach its destination and that must return to its original take-off location while being unable to complete its mission. |
| Ground team unable to access payload bay of sUAS | This hazard comes from the ground crew at the second site being unable to offload the supplies and/or unable to access the payload bay. Possible effects are a failure to drop off the supplies at the needed location and/or a return to the original take-off site without completing the mission. |

| | |
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| Crew unable to provide visual observations for sUAS #1 flight given plume opacity changes | This hazard comes from a required flight time of the sUAS missions extending beyond the visual observation capabilities of the crew as the plume prevents continued visual tracking of UAS and airspace and there is no BVLOS plan in place. Possible effects are that a mission must end and cannot support operations or a sUAS cannot be tracked so a RTB is required to ensure the crew can keep a visual on the UAS and the airspace. |
| Loss of communications between multiple UAS flight crews | This hazard comes from multiple sUAS flying at the same time in proximity and a lack of communication between each flight crew. Possible effects are a crash of the sUAS as flight routes cross, a near miss as some flight routes are manual while others are automated, or a RTB or rapid descent of a UAS to prevent a crash or near miss and continue safe operations for all UAS. |

Table 6. UAS Technical Issue Risk Category.

| **Risk Name** | **Risk Description** |
|---|---|
| Aircraft Fly Away | For this hazard, causes include pilot error, UAS subsystem failure, and/or interference from external sources. |
| Engine/Power Failure | With this hazard, causes include component failure, power starvation, or improper engine/motor tuning and operations. |
| Frequency Interference | This hazard causes include entities transmitting on or near UAS frequencies at high power levels. |
| GPS Signal Outage | The hazard could be a result of a loss of lock on the GPS satellite, aircraft flying into GPS denied area, or the aircraft flying into area where GPS signal is blocked by terrestrial entities, like buildings and vehicles. |
| Loss of Navigational Control | The hazard would be caused by pilot error, UAS subsystem error, ground control system error, and interference from external sources. |
| Loss of UAS C2 Link | With this hazard, causes include pilot error, UAS system error, ground control system error, and interference from external sources. |
| Stuck Landing Gear | For this hazard, causes include damaged linkages and failed equipment that leads to landing gear stuck in one position. Note that this hazard is more likely for a large fixed wing UAS but depending on the type of sUAS, the landing gear may retract upon take-off and get stuck. |
| Tire/Brake or Landing Gear Failure | Causes of this hazard include tire under/over inflation as well as wear for appropriate fixed-wing UAS. For other UAS that use landing gear rather than tires, then cracks in the landing gear or failure to engage can lead to failure. |
| Unrecoverable Onboard Failures/Malfunction | Causes of this hazard include power issues with onboard navigation, loss of power to motors if rotary sUAS, and or lack of response from onboard payload. |
| Loss of time synchronization between UASs used in response | This hazard would be caused by incorrect timing of missions [multiple aircraft] to match through centralized communications. Possible effects are aircraft taking off at the wrong time and data not comparable for evaluation of the disaster event. |
| Loss of power and navigational connection to large UAS in NAS | This hazard comes from a loss of power and control of the large UAS providing higher altitude view of the response. Possible effects are no higher altitude data to see the full extent of the event and/or act as a communications hub and a RTB or uncontrolled descent of the UAS. |

| | |
|---|---|
| Large UAS loss of power and navigational connection to large UAS in NAS | This hazard comes from a loss of power and control of the large. This would lead to no higher altitude data to keep observations on the full extent of the oil spill event and a RTB or uncontrolled descent of the UAS. |
| Loss of capability for one of two GCS used in mission | This hazard comes from loss of tracking of aircraft between two GCSs and an issue with switching control and being able to support operations. Possible effects are one GCS staying in control and being unable to track the UAS to its final location thus requiring RTB and the mission cannot be completed. |
| Loss of power and data transfer to tethered UAS | This hazard comes from a lack of continued power and data transfer across the UAS tether. Possible effects are that the tethered UAS must descend to obtain new batteries as power and mission loses the capabilities that the UAS provides. |
| Tether breaks on the sUAS | This hazard comes from a broken tether between the ground station and the airborne platform. Possible effects are a free flying UAS, that should be tethered to the ground, and does not have a pre-defined flight route and therefore is in fly-away mode. |

### 3.2 Mitigations

Based on the prior A28 results and newly collected case studies, the mitigations of common risks are summarized in the Tables 7-10. For instance, for the risk "Loss of Function of Tracking Antenna" under the category of "Deterioration of External Systems," the mitigation approach is "GCS parameters are set to ensure the aircraft returns to the assigned point in the event of a loss of link."

Table 7. Adverse Operating Conditions Risk Mitigation.

| **Risk Name** | **Risk Mitigation Description** |
|---|---|
| Collision into Terrain and Terrestrial Entities | The PIC will perform a controlled descent towards the terrain, population, built-up structures and/or vehicles/vessels. The choice of mission location will mitigate this risk by enclosing an area with sparse population and structures, avoiding built-up areas and heavily trafficked airways. The mission PIC will invoke a return to base or return to landing. This suspends the onward flight path and commands the UAS to return to base. The mission PIC will invoke a Divert Land Immediately (DLI), which suspends the onward flight path and commands the UAS to land at a designated landing zone, in a controlled manner at the maximum safe descent rate. |

| | |
|---|---|
| Mid-Air Collision | As a part of the safety case, the operators will submit details on the airspace characterization. The mission team will navigate with lights on UAS, use ADS-B compliant transponders, display ATC/ADS-B traffic maps for local traffic awareness, and immediately land or terminate flight. If the non-participating aircraft approaches UAS, such that UAS cannot avoid approaching aircraft's flight path, the team will conduct potential air traffic/airspace briefing with all crewmembers and participants and comply with ATC separation instructions. Under Part 107 operations, a visual observer would support the PIC to monitor the aircraft and airspace around it to minimize potential impact and have continued communications throughout the mission. Once the ATC (or VO) has identified traffic and an encounter is likely, the PIC will determine the exact avoidance maneuver to be utilized and will initiate that maneuver. The preferred order for invoking the avoidance maneuvers, in decreasing order of preference, will be used: Divert and Loiter > Return to Base > DLI> Terminate Flight. For BVLOS operations in uncontrolled airspace, radar systems (or other sensors to detect non-cooperative traffic) will be needed. |
| Rapid Onset of Inclement Weather or Disaster Specific Weather | During flight, if weather conditions deteriorate suddenly, the PIC assesses if DLI is required or if they can invoke RTB resulting in a suspension of the onward flight path. DLI will ensure that the flight lands safely as close as possible to the original location. If the PIC can determine that flight can still operate with the RTB in place, then the UAS will follow this pattern, i.e., its launch/landing point. If this is not possible given the weather conditions, the mission will use the defined landing zones developed in the CONOP to DLI. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Unexpected Winds Aloft | The mission team will request a local Pilot Report from any aircraft in the vicinity and/or flight team will obtain briefings every hour of the flight operations or obtain local weather data including winds aloft from accredited sources such as the National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS) for U.S. NAS missions. |
| Tethered sUAS #1 is close to people and property. Could fly away from control | The flight crew would have a PIC even with the UAS fixed to the building and in a fixed location. If the tether breaks, this PIC would take over manual operations for the UAS, return it to the fixed location, and hover to ensure continued operations. The PIC would communicate with operations to determine if available time to land UAS to fix the tether and resume full operation mode. If possible, the tether would be fixed. If not, UAS would be flown manually at the set location to provide the observations needed. |
| sUAS #2 is mobile and pushing the limits of VLOS. VO may lose sight of UAS | PIC and VO would be in constant contact to ensure that there is always a visual sighting on UAS and airspace. VO would inform the PIC if the flight route was reaching the extent of their visibility of the aircraft and airspace. PIC would inform operations to see if necessary to push beyond VLOS operations. If so, then extended VLOS would be assessed if possible. If BVLOS was needed, flight crew would determine if UAS has BVLOS capacity and request through SGI on a BVLOS waiver to continue operations. |
| sUAS #3 is performing a counterattack and is taken out of action | PIC for sUAS #3 will land the impacted UAS safely, either via return to landing or at a safe close location to the impact site. The sUAS #3 flight team will have a backup UAS with the same capabilities that can take off and provide counter UAS support. If all UAS #3 counter systems are impacted, then backup UAS will be acquired to ensure a minimum loss of time with no counter UAS support. |

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| sUAS #3 is performing delivery of supplies and the mechanism fails | PIC for sUAS #3 will land the impacted UAS safely, either via return to landing or at a safe close location to the impact site. The sUAS #3 flight team will have a backup UAS with the same capabilities that can take off and provide counter UAS support. If all UAS #3 counter systems are impacted, then backup UAS will be acquired from to ensure a minimum loss of time with no counter UAS support. |
| Terrorism event continues beyond one day and fatigue occurring in flight crews. | If the flight operations extend beyond the safe operational limits of the flight crew's working hours, then backup flight crews will be set-up to relieve the current operational teams. Debriefs will occur between each crew through the relevant PICs and in coordination with the operations team. This will minimize fatigue placed on the flight crews and minimize the risk of mistakes being made. |
| Lack of timing precision between missions prevents data from being compared. | The PICs and flight crew for each UAS will synchronize their flight clocks and sensor clocks with the same UTC timing system. This will be continuously monitored throughout the missions and rechecked and recalibrated after each flight. This will ensure that there are minimal time differences between the clocks of all the aircraft and sensors and support data comparison. |
| Severe Weather Conditions | During flight, if weather conditions deteriorate suddenly, the PIC assesses if DLI is required or if they can invoke RTB resulting in a suspension of the onward flight path. DLI will ensure that the flight lands safely as close as possible to the original location. If the PIC can determine that the flight can still operate with the RTB in place, then the UAS will follow this pattern, i.e., its launch/landing point. If this is not possible given the weather conditions, the mission will use the defined landing zones developed in the CONOP for DLI. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flights alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| sUAS are mobile and pushing the limits of VLOS. VO may lose sight of UAS. | PIC and visual observer will be in constant contact to ensure that there is always a visual sighting on UAS and airspace. VO will inform the PIC if the flight route is reaching the extent of their visibility of the aircraft and airspace. PIC will inform operations to see if necessary to push beyond VLOS operations. If so, then extended VLOS will be assessed if possible. If BVLOS is needed, flight crew will determine if UAS has BVLOS capacity and request through Significant Governmental Interest on a BVLOS waiver to continue operations. |
| Lack of fuel in lUAS performing multiple missions | The mission team will leave at least one hour of reserve fuel on board throughout the entire flight profile. The mission team will ensure that the flight checklists include details on population density and communities along their flight route. Alternative landing sites will be identified so that the PIC can manually fly the UAS to the new landing zone or the aircraft can be assigned to a new landing site if automated flight is still possible under safe operations. If there are multiple UAS flights at the same time and in the same airspace supporting disaster response, pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Eruption intensity dramatically changes while flight occurring | During this flight, the PIC will ensure that the UAS captures the data needed for the disaster response. The PIC will work with their flight crew to be informed on the future plume and cloud dispersal as well as the increase in volcano color code and seismic signals so that they can be prepared to manually fly the aircraft to locations where the observations needed can be collected and/or evacuate their location to find a new, safe site for operations as well as takeoff and landing. If this requires BVLOS operations, the crew will review if the permissions are in place to support this type of mission before proceeding. |

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| Ash/gas clouds move away from flight route for sUAS | During this flight, the PIC will ensure that the UAS can capture the data needed for the disaster response. The PIC will work with their flight crew to be informed on the future plume and cloud dispersal so that they can be prepared to manually fly the aircraft to locations where the observations needed can be collected. If this requires BVLOS operations, the crew will review if the permissions are in place to support this type of mission before proceeding. The action will ensure safe flight operations and a minimizing of the risk placed on the aircraft and/or flight crew. |
| Toxic ash and gases | The Pilot in Command will perform controlled flight operations to move the aircraft away from the toxic level of ash and gases. The PIC will assess if the levels of ash and gas in the atmosphere limit the ability of the UAS to operate and the crew to continue to operate. The PIC will determine if a RTB or RTL is required or if the aircraft can continue its operations. The mission PIC will invoke a DLI, which suspends the onward flight path and commands the UAS to land at a designated landing zone, in a controlled manner at the maximum safe descent rate. |
| Ash/gas clouds move away from flight route | During this flight, the PIC will ensure that the UAS can capture the data needed for the disaster response and could be flying a defined flight path. The PIC will work with their flight crew to be informed on the future plume and cloud dispersal so that they can be prepared to manually fly the aircraft to locations where the observations needed can be collected. If this requires VLOS operations, the crew will review if the permissions are in place to support this type of mission before proceeding. |

Table 8. Deterioration of External Systems Risk Mitigation.

| **Risk Name** | **Risk Mitigation Description** |
|---|---|
| Generator Failure [on-board] | Mitigation would include assigning ditch points for the UAS in the CONOP so that the team is prepared for safe landings if unable to return to home. Also, crew members responsible for mission team safety and the GCS should inform the PIC or mission manager on loss of power. Depending on the vehicle's capabilities, it may not be possible to reach a prescribed ditch point during a power loss. However, if the vehicle can reach the ditch point, these points should be monitored for pedestrian/ground traffic to ensure safe landing is possible. VOs in place for VLOS operations will be used to support the PIC in understanding any risks on the ground below the aircraft's location when power is lost. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Generator Failure [ground-based for GCS] | Mitigation includes continued communication between PIC, VOs, mission lead, and engineering team on the available backup battery power for all GCS systems to ensure that flight can be completed before unsafe conditions occur. Additionally, flight checklists ensure that backup generator power is available in remote locations where main power is unavailable. If battery power for GCS systems is running low, the PIC will follow mitigation plans for DLI if unable to return to the landing zone. If the aircraft can return, the RTB will be invoked when the PIC determines it is needed to ensure safe operations and that the aircraft can return. |
| Loss Function of Tracking Antenna | GCS parameters are set to ensure the aircraft returns to the assigned point in the event of a loss link. |

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| Loss of the Ground Control Station (GCS) | Upon loss of the GCS, the PIC will intervene and take control of the UAS using a separate hand-held radio controller, operating on a different C2 link frequency, and command it to return to base. Additionally, for BVLOS operations, a loss of the GCS will result in a loss of the C2 link from the GCS. At this point, the flight team will use the lost link contingency procedures. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| lUAS is unable to stay airborne or takes too long to launch | The lUAS team will react as quickly as they are requested to support the disaster response. They will know the available airports that they can use for their flight operations and will have their own flight checklists for flight operations. The lUAS team that assets are closest to the disaster response will be contacted first to ensure fast response. The disaster response team will know the available large UAS teams that are approved to support disaster response. The lUAS flight crew will inform the ICS lead/air boss of their currently available fuel and time that they can stay airborne. |
| Large UAS flies from National Airspace System to temporary airspace restriction zone. | Flight crew and PIC coordinate with the operations center and air boss for emergency response so that they are aware at all times of the location of the lUAS. PIC and flight mission lead will set up all permissions before any missions start to ensure that the large UAS can respond to all needs of the response and enter and leave the TFR when needed. |
| Large UAS needs refueling and loose higher altitude observations | Mobile sUAS switches roles from proximity to higher altitude data collection so that the impact of the lUAS being on the ground is minimized. The mobile UAS may need to land for battery replacement, but this will be minimal and will not cause major impact on the higher altitude full airport extent observations. |
| Lack of safe landing for flight operations over water | Before the mission, the PIC of the sUAS will determine a range of potential landing locations if there is an issue with the aircraft as it flies over the water or if the visual observer is unable to track the aircraft. Zones on land will be defined as alternates for the boat landing site used for the oil spill analysis. All backup landing sites will be chosen to ensure safe landing and that the aircraft can land away from any water. If the only option is to land on water, the PIC and flight crew will use RTB to ensure a reusable UAS and if not possible will instigate a safe DLI procedure. |
| Lack of safe landing for sUAS #1 flight operations over water | Before the mission, the PIC of the sUAS will determine a range of potential landing locations if there is an issue with the aircraft as it flies over the water or if the visual observer is unable to track the aircraft. Zones on land will be defined as alternates for the boat landing site used for the oil spill analysis. If the only option is to land on water, the PIC and flight crew will use RTB to ensure a reusable UAS and if not possible will instigate a safe DLI procedure. |
| Toxic ash and gasses concentrations along flight routes | PIC will perform controlled flight operations to move the aircraft away from the toxic level of ash and gas. The PIC will assess if the levels of ash and gas in the atmosphere limit the ability of the UAS to operate and the crew to continue to operate. The PIC will determine if a RTB or RTL is required or if the aircraft can continue its operations. The mission PIC will invoke a DLI, which suspends the onward flight path and commands the UAS to land at a designated landing zone, in a controlled manner at the maximum safe descent rate. |

Table 9. Human Factors Risk Mitigation.

| **Risk Name** | **Risk Mitigation Description** |
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|---|---|
| Physiological Human Factors Event | During the pre-flight brief, the PIC will check to ensure that the flight team can complete the planned flight. Only a flight team that can complete the CONOP will be able to be a part of the mission. Pre-flight briefings will be used to ensure all crew members are aware of their responsibilities. |
| Loss of Communications Between Crew Members | The mission team will ensure that UAS PIC, Crew, ATC communications plan, call sign and protocols are briefed at each pre-flight briefing. Also, the team will ensure spare batteries are available for all communication devices. Note that loss of communications between PICs, VOs (or personnel used for SAA requirements), and/or ATC may be grounds for termination of flight operations. The PIC will assess this based on the mission and their situational awareness on the location of the airspace and aircraft. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Loss of Communications Between Flight Crew and ATC | Mission team will ensure that UAS PIC, Crew, ATC communications plan, call signs, and protocols are briefed at each pre-flight briefing. Including a satellite phone in the mission checklist will ensure that additional communication equipment will mitigate this hazard impacting flight operations. Note that loss of communications between PICs, VOs (or personnel used for SAA requirements), and/or ATC may be grounds for termination of flight operations. The PIC will assess this based on the mission and their situational awareness on the location of the airspace and aircraft. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Non-crew Member Interruption of Flight Crew | Before take-off, the PIC will remind those present of the sterile control station requirements. Also, a crew member not performing PIC or VO duties is assigned to brief any approaching spectator. This role should be laid out in the roles and responsibilities section of the CONOP. Finally, before the landing the PIC should re-brief the mission team and its vicinity on the sterile control station procedure and environment. |
| Crew unable to provide visual observations for sUAS flight | Before the mission starts, the PIC will determine the maximum distance that a VO can see to ensure VLOS operations based on the conditions at the time of flight. The VO will continue to stay in communication with the PIC to ensure that they can confirm that they can see the aircraft and the airspace around the operations. If there is a deviation of the planned flight route, then the PIC will ensure that the VO can still see the aircraft, and if no onboard DAA system is in place and no waiver to allow BVLOS operations then the new route will not occur and the aircraft will stay on its course that ensure VLOS operations. |
| Crew unable to ensure safe operations over people and/or property | Before the mission starts, the PIC will define all of the backup landing zones in case there is an issue with the flight operations. The VO will continue to track the aircraft and airspace and inform the PIC if they are unable to continue this role. If there is a loss of sight of the aircraft by the VO, then the PIC will invoke a DLI or RTB depending on the location and proximity to people and property. The flight mission will have all required permissions to allow them to fly over people and the environment below the flight path. |
| sUAS flight crew unable to ensure safe operations over people and/or property | Before the mission starts, the PIC will define all the backup landing zones in case there is an issue with the flight operations. The VO will continue to track the aircraft and airspace and inform the PIC if they are unable to continue this role. If there is a loss of sight of the aircraft by the VO, then the PIC will invoke a DLI or RTB depending on the location and proximity to people and property. |

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| | The flight mission will have all required permissions to allow them to fly over people and the environment below the flight path. |
| Loss of communications between crews at two GCS | Before the mission starts, the two PICs will check all communications between the two GCSs and backup communication tools that they are using to ensure that at least one GCS is tracking the UAS. They will have a procedure setup on how to perform the handoff between the two GCSs and their contingency plan if they lose communications. If there is a drop in communication, the original take-off site will stay in control of the UAS tracking as they would have been the lead until the handover. If there is no return to joint communications, then the take-off site PIC will set the RTB on the aircraft, and this will inform the second GCS PIC that the communication issue has prevented them from completing the mission. |
| Ground team unable to access payload bay of lUAS | The ground team at each site will be trained in how to access the payload bay for the sUAS and will have communications with the two PICs at the GCS as well as the flight teams. Depending on the mission type, the ground team can be part of the flight team. The ground team will follow the safety procedures for the aircraft to determine where the issues reside and if this can be fixed on site using their flight crew's equipment. If the payload bay cannot be opened, then the flight crew will take over and ensure that the aircraft is safe for its return flight back to the original take-off site. Then this site will have the equipment needed to fix the payload bay issue and support another mission to deliver the payload contents. |
| Loss of capability for one of two GCS used in mission | Covered under the mitigation plan for the “Loss of communications between crews at two GCS” section above. |
| Ground team unable to access payload bay of sUAS | The ground team at each site will be trained in how to access the payload bay for the sUAS and will have communications with the two PICs at the GCS as well as the flight teams. Depending on the mission type, the ground team can be part of the flight team. The ground team will follow the safety procedures for the aircraft to determine where the issues reside and if this can be fixed on site using their flight crew's equipment. If the payload bay cannot be opened, then the flight crew will take over and ensure that the aircraft is safe for its return flight back to the original take-off site. Then this site will have the equipment needed to fix the payload bay issue and support another mission to deliver the payload contents. |
| Crew unable to provide visual observations for sUAS #1 flight given plume opacity changes | Before the mission starts, the PIC will determine the maximum distance that a VO can see to ensure VLOS operations based on the conditions at the time of flight. The VO will continue to stay in communication with the PIC to ensure that they can confirm that they can see the aircraft and the airspace around the operations. If there is a deviation of the planned flight route, then the PIC will ensure that the VO can still see the aircraft, and if no onboard DAA system is in place and no waiver to allow BVLOS operations then the new route will not occur, and the aircraft will stay on its course that ensure VLOS operations. |

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| Loss of communications between multiple UAS flight crews | Before the mission, each PIC will check their communications between their flight location and the centralized mission team and with the other PICs and their flight crew. The different UAS flight teams will ensure that each is aware of the communication frequencies to use and the call signs and terms that each team will be using. Each flight team will be able to see the location of the other UAS in their flight management software and if needed can communicate through the centralized mission team. One flight team member will be able to communicate with the other teams and will not take on the PIC or VO role for the flight. Each team will have backups in case their communications drop with the operational radio and if these fail, they will perform a DLI or RTB that will demonstrate to the other teams that their communications are broken and cannot perform safe operations. |

Table 10. UAS Technical Issue Risk Mitigation.

| **Risk Name** | **Risk Mitigation Description** |
|---|---|
| Aircraft Fly Away | The PIC will ensure that the flight plan coordinates are verified before uploading to the aircraft. Additional equipment available to the PIC will be used to communicate with those leading the disaster response, any nearby general traffic in the airspace and/or other UAS support a disaster response. If the fly away extends beyond the disaster response area, then any local ATC will be informed using the same channels used to connect when briefing them of UAS operations. |
| Engine/Power Failure | The mission team will leave at least one hour of reserve fuel on board throughout entire flight profile if lUAS or sufficient power for return to home for battery based sUAS. The mission team will ensure that the flight checklists include details on population density and communities along their flight route. Also, alternative landing sites will be identified so that the PIC can manually fly the UAS to the new landing zone or the aircraft can be assigned to a new landing site if automated flight is still possible under safe operations. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Frequency Interference | The mission team will track the C2 frequency strength between GCS and aircraft. Additionally, the PIC will ensure that the flight checklist has information on the C2 coverage throughout the flight route. |
| GPS Signal Outage | If a loss of GPS signal occurs during the in-flight phase of the operations, the UAS will begin to loiter in place. If the UAS has not reestablished a GPS link in one minute, the PIC will command avoidance DLI. This will suspend the onward flight path and cause the UAS immediately to descend, at its maximum safe descent rate, from the current location to land in a controlled manner. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |

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| Loss of Navigational Control | Navigational coordinates will be verified before uploading to the UAS. UAS will be commanded to return to landing zone immediately if loss of navigation control to minimize time spent dead reckoning. For BVLOS operations, the PIC will divert and land/land immediately, suspending the onward flight path and commanding the UAS to descend and land from its current location, in a controlled manner, at its maximum safe descent rate. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Loss of UAS C2 Link | There are four actions here to support safe flight operations: 1. ensure that the loss of C2 link return home routing does not conflict with air traffic routes including altitudes; 2. monitor common area traffic frequencies, 3. publish a NOTAM a minimum of 24 hours before flight, and 4. notify known airspace uses of UAS flight activity. Additionally, the PIC will ensure that the flight checklist has information on the C2 coverage throughout the flight route. |
| Stuck Landing Gear | The team will have the aircraft loiter over the landing zone while still staying within safe fuel/battery power limits. This will allow the team to assess a safe landing location and process. |
| Tire/Brake or Landing Gear Failure | Performing safe flight tests before the mission will support the mission team to check the landing gear safety as well as pre-flight checks of the airframe will allow the team to assess any maintenance issues and minimize the likelihood of this risk impacting flight operations. |
| Unrecoverable Onboard Failures/Malfunction | BVLOS operations will be contingent on the airspace situation, i.e., depending on whether surveillance systems detect an intruder. The PIC will suspend the flight and invoke RTB, commanding the UAS to return to base; or DLI, commanding the UAS to suspend the current plan, divert to the nearest safe area, and descend at its maximum safe descent rate to controlled landing. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. On the other hand, if the failure/malfunction onboard the UAS during flight leads to an unrecoverable loss of control state, then If the C2 link continues to be available (contingent on the airspace situation) the PIC will command either DLI, commanding the UAS to descend from its current location at its maximum safe descent rate to a controlled landing, or TER, resulting in a shutdown of the UAS engines. However, if the C2 link is also unavailable, the emergency procedures applicable for a sustained loss of the C2 link will be utilized. |
| Loss of time synchronization between UASs used in response | Before all of the missions start, the flight crews will ensure that aircraft systems and GCSs are synchronized so that data can be compared. Between flights, the crew will re-assess the time synchronization of their systems and be in communication with the central team to ensure operations occur at the time specified in the CONOP |

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|---|---|
| Loss of power and navigational connection to lUAS in NAS | Mitigation would include assigning ditch points for the UAS in the CONOP so the team is prepared for safe landings, if unable to return to home. The crew member responsible for mission team safety and the ground control station will inform the PIC or mission manager on loss of power. Depending on the vehicle's capabilities, it may not be possible to reach a prescribed ditch point during a power loss. However, if the vehicle can reach the ditch point, these points should be monitored for pedestrian/ground traffic to ensure safe landing is possible. VOs in place for VLOS operations will be used to support the PIC in understanding any risks on the ground below the aircraft's location when power is lost. If there are multiple UAS flights at the same time and in the same airspace supporting disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| lUAS loss of power and navigational connection to lUAS in NAS | PIC for lUAS would assign ditch points so the team is prepared for safe landings, if unable to return to home. The crew member responsible for mission team safety and the ground control station will inform the PIC or mission manager on loss of power. Depending on the vehicle's capabilities, it may not be possible to reach a prescribed ditch point during a power loss. However, if the vehicle can reach the ditch point, these points should be monitored for pedestrian/ground traffic to ensure safe landing is possible. If one of the sUAS flights is in the vicinity of a ditch location and in the same airspace, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights. |
| Loss of capability for one of two GCS used in mission | Before the missions start, the two GCS crews will be in communication and ensure that they have backup power. Also, the PICs will be aware of the geographical limitations of their tracking capabilities and the procedures to follow if one GCS is unable to operate. The lead organization that is operating the GCS will share its safety management system with the disaster response team leads so all are aware of procedures should this hazard occur. If one GCS does lose capability, the PIC at the functioning GCS will continue to be in control of the UAS and will work with their flight crew to ensure safe operations. If required, a DLI will be used or a Return to Land to the original take-off site or to a safe chosen landing site. |
| Loss of power and data transfer to tethered UAS | Before the mission starts, the PIC for the tethered UAS will perform safety checks for the tethering system and check that power and data can be received by the aircraft and data sent back to the ground station. If there is a drop in power and data transfer, the PIC and their flight team will monitor the issue. Once it reaches close to their safety limits, the aircraft will descend with sufficient power to ensure a safe landing. All data collected will be removed from the onboard sensors and the power issue evaluated. If possible, the aircraft will return to its tethered altitude to provide the support needed. |
| Tether breaks on the sUAS | The PIC for the mission will take over manual control of the aircraft and either perform a DLI or RTB for the aircraft. The flight crew will use a sUAS that can be both a tethered UAS with data transfer and power provided by the tethered as well as a mobile UAS that can be manually controlled by the flight PIC. The flight crew will have a VO that can act if the aircraft does fly away from its tether and will communicate with the PIC. |

### 3.3 CONOPs and ORA for Specific Use Cases Identified

The team has collected and summarized a risk assessment based on results from A28 and new use cases from A52. Below, Table 11 presents the risk description and relevant risk level. The descriptions of risk levels are shown in Figures 124 and 125. For example, the risk of "Mid-Air

Collision" is classified as C1 with a red color. According to Figure 124, if the UAS is a sUAS, the likelihood of the risk is "remote" and the severity of the risk is "Catastrophic."

Table 11. Risk Level for Specific Use Cases.

| **Risk Category** | **Risk Description** | **Risk Level** |
|---|---|---|
| Adverse Operating Conditions | Collision into Terrain and Terrestrial Entities | C2 |
| | Mid-Air Collision | C1 |
| | Rapid Onset of Inclement Weather or Disaster Specific Weather | B3 |
| | Unexpected Winds Aloft | D3 |
| Deterioration of External Systems | Generator Failure [on-board] | C3 |
| | Generator Failure [ground-based for GCS] | C3 |
| | Loss Function of Tracking Antenna | C3 |
| | Loss of the Ground Control Station (GCS) | C3 |
| Human Factors | Physiological Human Factors Event | C3 |
| | Loss of Communications Between Crew Members | C3 |
| | Loss of Communications Between Flight Crew and ATC | C3 |
| | Non-crew Member Interruption of Flight Crew | C3 |
| UAS Technical Issue | Aircraft Fly Away | B2 |
| | Engine/Power Failure | C3 |
| | Frequency Interference | D2 |
| | GPS Signal Outage | C3 |
| | Loss of Navigational Control | D2 |
| | Loss of UAS C2 Link | C2 |
| | Stuck Landing Gear | C3 |
| | Tire/Brake or Landing Gear Failure | D3 |
| | Unrecoverable Onboard Failures/Malfunction | C3 |

| Severity / Likelihood | Minimal 5 | Minor 4 | Major 3 | Hazardous 2 | Catastrophic 1 |
|---|---|---|---|---|---|
| Frequent A | [Green] | [Yellow] | [Red] | [Red] | [Red] |
| Probable B | [Green] | [Yellow] | [Yellow] | [Red] | [Red] |
| Remote C | [Green] | [Green] | [Yellow] | [Yellow] | [Red] |
| Extremely Remote D | [Green] | [Green] | [Yellow] | [Yellow] | [Red] [Yellow] |
| Extremely Improbable E | [Green] | [Green] | [Green] | [Green] | [Yellow] |

| Risk Matrix – General Aviation Operations/Small Aircraft and Rotorcraft | * = High Risk with Single Point and/or Common Cause Failures |
|---|---|
| Referenced from Figure C-2: FAA Order 8040.4B Appendix C, C-4 [Page 30 of PDF]; Figure C-1: FAA Order 8040.4B, Appendix C, C-1 [Page 21 of PDF] | |

| |
|---|
| High Risk [Red] |
| Medium Risk [Yellow] |
| Low Risk [Green] |

Figure 124. sUAS Risk Metrics.

| Severity / Likelihood | Minimal 5 | Minor 4 | Major 3 | Hazardous 2 | Catastrophic 1 |
|---|---|---|---|---|---|
| Frequent A | [Green] | [Yellow] | [Red] | [Red] | [Red] |
| Probable B | [Green] | [Yellow] | [Red] | [Red] | [Red] |
| Remote C | [Green] | [Yellow] | [Yellow] | [Red] | [Red] |
| Extremely Remote D | [Green] | [Green] | [Yellow] | [Yellow] | [Red] |
| Extremely Improbable E | [Green] | [Green] | [Green] | [Yellow] | [Red] [Yellow] |

| Risk Matrix – Commercial Operations/Large Transport Category | * = High Risk with Single Point and/or Common Cause Failures |
|---|---|
| Referenced from Figure C-1: FAA Order 8040.4B, Appendix C, C-3 [Page 29 of PDF] | |

| |
|---|
| High Risk [Red] |
| Medium Risk [Yellow] |
| Low Risk [Green] |

Figure 125. lUAS Risk Metrics.

## 3.4 Predictive Risk Assessment

Based on the information presented in Table 11, several risks associated with special use cases have been identified and assessed by experienced professionals. However, evaluating risks for other potential events is challenging due to a lack of adequate experience and knowledge. Recognizing the urgency of capturing and estimating risks, the researchers suggest employing a ML approach to gauge the levels of risk. The researchers currently possess information comprising risk descriptions and corresponding risk levels as outlined in Table 11. Additionally, the team has gathered several other use cases, each accompanied by a risk description; however, there are no associated risk levels for these cases. The proposal involves assessing the similarities in risk descriptions between the collected use cases (lacking risk levels) and the documented risk events with levels presented in Table 11. In this approach, the team suggests assigning the risk level to a use case based on the risk events in Table 11 with the most similar description. Figure 126 presents the logical flow of the proposed predictive risk assessment.

In order to capture similarity, the researchers propose using different embeddings and a Siamese Manhattan LSTM approach. Figure 127 shows an example of using Siamese Manhattan LSTM to compare similarity.

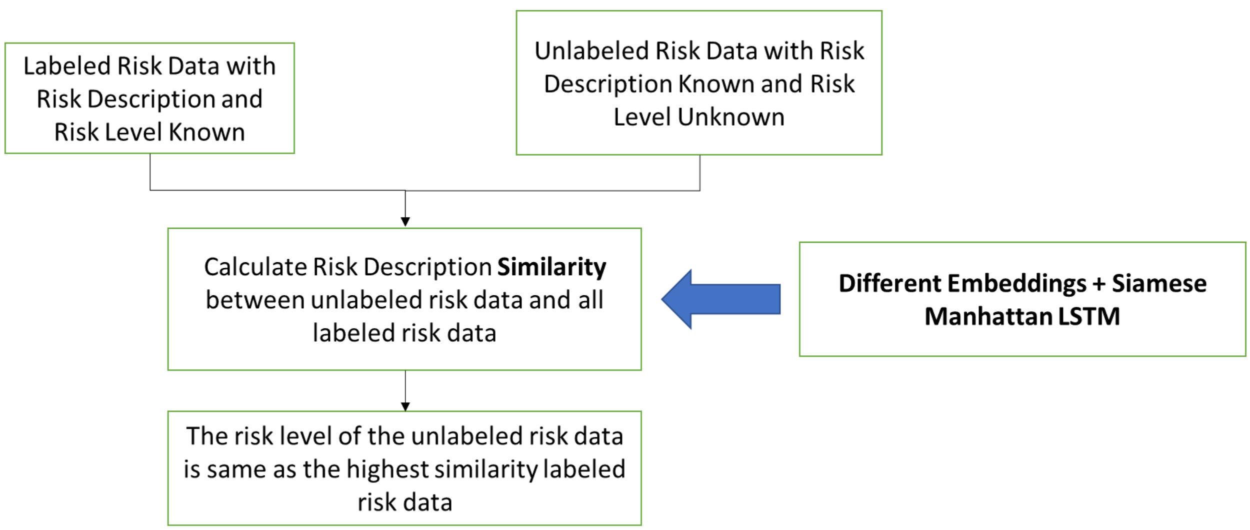


Figure 126. Predictive Risk Assessment Logic Flow.

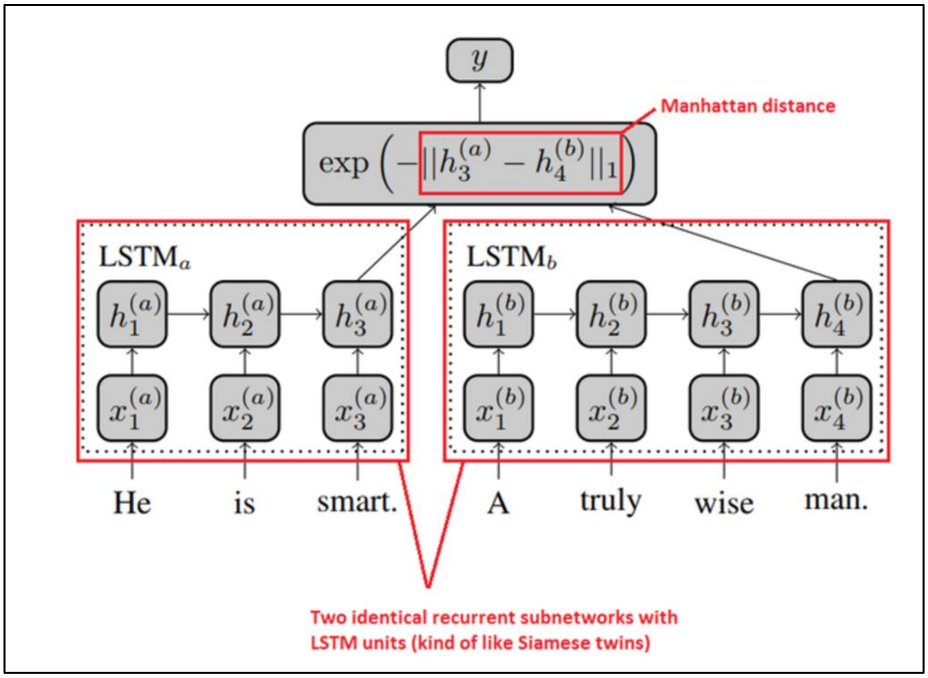


Figure 127. Siamese Manhattan LSTM Example.

Applying the same approach, the risk levels of the collected use cases are summarized in Table 12. It should be noted that the predicted results may not be as accurate as evaluations by professionals. One possible reason for this discrepancy is that the labeled dataset (as shown in Table 11) is not sufficiently large.

Table 12. Predicted Risk Level of Use Cases.

| **Risk Description of Use Cases** | **Risk Level** |
|---|---|
| Tethered sUAS #1 is close to people and property. Could fly away from control | C2 |
| sUAS #2 is mobile and pushing the limits of VLOS. VO may lose sight of UAS | C3 |
| sUAS #3 is performing a counterattack and is taken out of action | C2 |
| sUAS #3 is performing delivery of supplies and the mechanism fails | C3 |
| Terrorism event continues beyond one day and fatigue occurring in flight crews. | C1 |
| Lack of timing precision between missions prevents data from being compared. | C2 |
| Severe Weather Conditions | B2 |
| sUAS are mobile and pushing the limits of VLOS. VO may lose sight of UAS. | C3 |

| **Risk Description of Use Cases** | **Risk Level** |
|---|---|
| Lack of fuel in lUAS performing multiple missions | D2 |
| Eruption intensity dramatically changes while flight occurring | C2 |
| Ash/gas clouds move away from flight route for sUAS | C2 |
| Toxic ash and gases | C2 |
| Ash/gas clouds move away from flight route | C3 |
| lUAS is unable to stay airborne or takes too long to launch | C3 |
| lUAS flies from National Airspace System to temporary airspace restriction zone. | C3 |
| lUAS needs refueling and loose higher altitude observations | B2 |
| Lack of safe landing for flight operations over water | B2 |
| Lack of safe landing for sUAS #1 flight operations over water | B2 |
| Toxic ash and gasses concentrations along flight routes | C2 |
| Crew unable to provide visual observations for sUAS flight | C3 |
| Crew unable to ensure safe operations over people and/or property | C3 |
| sUAS flight crew unable to ensure safe operations over people and/or property | D2 |
| Loss of communications between crew at two GCS | D2 |
| Ground team unable to access payload bay of lUAS | C2 |
| Loss of capability for one of two GCS used in mission | C3 |
| Ground team unable to access payload bay of sUAS | C2 |
| Crew unable to provide visual observations for sUAS #1 flight given plume opacity changes | C3 |
| Loss of communications between multiple UAS flight crews | B2 |
| Loss of time synchronization between UASs used in response | C3 |
| Loss of power and navigational connection to lUAS in NAS | B2 |
| lUAS loss of power and navigational connection lUAS in NAS | B2 |
| Loss of capability for one of two GCS used in mission | C2 |
| Loss of power and data transfer to tethered UAS | C2 |
| Tether breaks on the sUAS | C3 |
| Loss of time synchronization between UASs used in response | C2 |

# 4 PROCEDURES AND GUIDELINES

## 4.1 Recommended Policies, Procedures and Guidelines for UAS flight Coordination and Use in a Disaster to Assure the Safe, Effective and Efficient Use of UAS in Local, State and Federal Responses

The completion of the events – seminars, drills, tabletop exercises, and mock exercises – executed by this team has led to several conclusions and recommendations reflected and derived from the lessons learned. These are summarized in the following sections.

### *4.1.1 The need exists for a unique regulatory framework that is quickly brought to bear when a disaster is taking place.*

Regardless of the scope of the emergency or its nature (e.g., residential fire, major fire conflagration, wildfire, flood, landslide, major industrial accident or emergency, train wreck, weather event such as hurricane or tornado, etc.), there needs to be a set of specialized, temporary regulations and practices imposed on the event and its surroundings. These regulations might include control of UAS from hobbyists and the press as well as those being operated by first responders. Certainly, the qualifications of the responders should be measured, documented, and made known to local incident commanders. There is also a clear need for rapid approval of applicable airspace regulations relating to the disaster at hand; for example, TFR or expedited approval through the SGI process. The existing state of affairs, as reflected in some actual disasters to which members of this team responded, is that current practice with regard to TFRs and SGIs is simply too slow to meet the needs of emergency responders.

### *4.1.2 There is a need for a set of uniform practices and standards at local, state, and federal level with regard to privacy when collecting emergency-related imagery.*

Currently, there is a broad set of definitions of and requirements relating to privacy at the different levels of government. When responding to a disaster, it is nearly impossible for the first responder using UAS technology to be certain of all the restrictions that may apply to the collected imagery.

### *4.1.3 There exists a need for a standardized set of performance and skill levels possessed by individual UAS pilots for an Incident Commander to make best use of the pool of UAS pilots present at an incident.*

There is currently no method by which UAS pilots are graded other than the Part 107 Remote Pilot certification process. This is a question-and-answer process that fails to indicate the individual's piloting skills, safety practices, experience, understanding and application of risk management, and other factors that define their value to the air operations manager or incident commander. This team has taken the initiative to enumerate and define a set of MOPS that will ultimately fulfill this need.

The team established a set of basic topics and skills that experience suggests are required to define competence in a pilot expected to respond to an emergency. These required elements are:

1. Pilot Dexterity and Skills
2. Visual Acuity/SAR
3. Understanding of Airspace Operations
4. Familiarity with UAS

5. Risk Analysis
6. Safety Best Practices
7. Knowledge of the NIMS/ICS
8. Understanding of Applicable Regulations
9. Communications Knowledge and Skills
10. Knowledge of Sensors
11. Knowledge of Data Products

The team then convened and developed a further definition of the broader definition of these terms as they would be applied in a process of training, testing, and evaluating candidate UAS pilots. These are summarized in Table 13.

Table 13. Delineation of the proposed Minimum Operational Proficiency Standards.

| **Minimum Operational Proficiency** | **MOP Clarification** |
|---|---|
| Pilot Dexterity and Skills | Demonstrated ability to manually maneuver an assigned aircraft with skill and precision when not flying waypoints. |
| Visual Acuity/SAR | Demonstrated ability to scan, isolate, and identify target video or thermal images in various operational settings that simulate actual SAR missions. |
| Airspace Operations | Knowledge of and compliance with regulatory framework governing disaster response UAS flying, Including flights near airports (LAANC procedures). |
| Familiarity with UAS | Ability to identify and explain various components of both fixed wing and rotary wing UAS and to explain their functions. Ability to identify preferable aircraft for various emergency response situations and assignments. |
| Risk Analysis | Knowledge of sources of potential risk within specific types of emergency response operations; understanding of various mitigation strategies to minimize risk. |
| Safety Best Practices | Awareness and exercise of prescribed safety doctrine and operational procedures. Demonstrated knowledge of institutional safety doctrine. |
| Operating Within an Incident Structure | Thorough understanding of FEMA’s Incident Command Structure and ability to explain where UAS operations fit within the structure. |

| | |
|---|---|
| Understanding of Applicable Regulations | Knowledge of all Federal, State, and Local regulations applying at the time and location of disaster response operations, including temporary governing conditions (e.g., Special Governmental Interest waivers). |
| Communications Knowledge and Skills | Knowledge and appropriate use of specified channels of communications, both voice and text, established for a disaster or emergency response incident. |
| Knowledge of Sensors | Ability to determine the capabilities and limitations of available sensors. Knowledge of when and on what available aircraft specific sensors should be used for assigned missions. |
| Knowledge of Data Products | Demonstrated awareness of the kinds of data being collected and aggregated on a certain mission. Knowledge of how/where (local or remote) the data is to be processed and to whom it will be ultimately delivered. |

The team intends to expand this effort under the Phase III research agreement to produce a pilot training and credentialing process that would serve to correct this deficiency in the current environment. Ideally, this concept would evolve into recognized levels of mastery, not unlike manned aviation credentials.

### 4.2 UAS Procedures and Guidelines to Follow for Emergency Response that can be Cross Cutting Across the NAS to Ensure Proper Coordination

Firstly, the UAS operators in a disaster must always operate under Incident Command and complete all current training to ensure mission success. Additionally, all staff must understand the importance of regulatory limitations (such as state and local laws), FAA emergency operational procedures, and airspace designations and processes. Before any disaster response operations begin, risk and safety analyses must be conducted. Operations must always use Part 107 for standard practice across the NAS. Finally, drone selection must match the disaster need.

### 4.3 Categories of Vehicles Needed for each Mission Type and How the UAS Chosen can Change the Procedures

Much of the research on preferable aircraft types for various disaster response roles was performed under the Phase I research effort and reflected in the CONOPs. In general, fixed wing aircraft are most valuable for oversight flights, medical deliveries, and mapping operations. Multicopters are more appropriate for SAR, damage assessment, and close-in imagery collection. Each team seems to develop affinities for particular aircraft and sensor configuration for use in individual applications. This may be based on experience or simply a budget decision or aircraft /sensor gifted to an institution or organization.

The playing field is evolving so rapidly for both aircraft and sensor technology that it would be meaningless to produce a “best aircraft” listing for particular uses, as the list would be obsolete within days. Furthermore, a “best solution” is dependent on many factors such as an organization’s budget and pilot skills that are beyond the scope of a technical assessment.

## 4.4 Procedures and Guidelines Research Questions:

### *4.4.1 Based on the mock demonstrations, lessons learned, and coordination with standard bodies, what are the final set of policies, procedure, guideline and waiver sets to employ using UAS in a disaster or emergency response?*

Policies, procedures, guidelines, and waiver sets need to include pilot qualification/certification, interagency coordination/collaboration, airspace emergency management, standardization of privacy and liability regulations, and cross-agency communications standardization.

### *4.4.2 What standards should be developed with standard bodies?*

Standards are needed for pilot qualification/certification, airspace emergency management, standardization of privacy and liability regulations, and cross-agency communications standardization.

### *4.4.3 Coordination and Industry Standards Engagement working with standard bodies, NASA, UAS Test Sites, ASSURE projects and disaster and emergency response organizations*

A disaster response use of uncrewed vehicles working group, including federal, state, and local governments, specialized existing response groups (e.g., Missouri TF1, NYFD), regulatory agencies, and representative first responders from all levels needs to be established to address the issues encountered in the simulated and actual disasters described herein.

UAH conducts monthly bill tracking to maintain a database of federal regulatory changes that includes bills that have been introduced but not yet acted upon. The organization performs this survey to remain proactive on any actionable bills that might present an opportunity or have an adverse effect on the UAS community or introduce significant change to the UAS operating environment. Typical output is shown in Figure 128.

**Drones for First Responders Act**

Bill Status

House Bill 8416:

Sponsor: Rep. Stefanik, Elise M. [R-NY-21]

Introduced: 5/15/2024

Committee: Ways and Means; Transportation and Infrastructure; Agriculture

Current Status: Introduced

Latest Action: 5/15/2024 - Referred to the Committee on Ways and Means, and in addition to the Committees on Transportation and Infrastructure, and Agriculture, for a period to be subsequently determined by the Speaker

Bill Summary

This bill amends Subchapter III of chapter 99 of the Harmonized Tariff Schedule of the United States in order to increase the tariffs for unmanned aircraft that are the product of China. This bill would progressively increase the duty rate according to the following schedule:

| Time After Enactment | New Duty Rate |
|---|---|
| 30 days | 30% |
| 1 year | 35% |
| 2 years | 40% |
| 3 years | 45% |
| 4 years | $100 each + 50% |

In addition, Section 5 of this bill would establish a fund known as the "Secure Unmanned Aircraft Systems for First Responders Fund". The fund is to be used for a grant program that would provide yearly grants to first responders, farmers and ranchers, and providers of critical infrastructure to purchase new, secure UAS.

Figure 128. Typical output of UAH Bill Tracker Application.

### *4.4.4 How will the policies, procedures, and guidelines be disseminated across the local, state and national first responder community? Web, social media, etc.*

Numerous existing websites and social media sites do a good job of disseminating policies, procedures, guidelines, training materials, and tests. The FEMA training site, https://training.fema.gov/ is an excellent example. The website of the National Institute of

Standards and Technology (part of the Department of Commerce) is another superb example at https://www.nist.gov/. Any other organization that needs to disseminate this kind of information can use existing resources as "go-by" examples of effective dissemination.

#### *4.4.5 What training or guidance do agencies require with respect to the waiver process?*

Understanding of the waiver process(es) varies significantly between and among agencies and individual responders. There is no apparent pattern.

#### *4.4.6 What technological advancements might negate the need for certain waivers?*

Opportunities should be examined for online waiver processing in cases where that option does not currently exist. Another opportunity to expedite the issuing of certain urgent waivers might be some "pre-approval" process in which a specific event might automatically trigger the issuing of needed emergency waivers. A good example might be pre-approved TFRs and SGIs in areas known to be affected by hurricanes. These waivers would be triggered over a specified area whenever a storm of known destructive power approaches that region.

# 5 LESSONS LEARNED

The lessons learned from the exercises are contained in Appendix A. The lessons learned for all the lesser events, drills, tabletops, seminars, and workshops, have been interwoven with the research questions listed in each event write-up in Sections 2.1 through 2.29.

# 6 CONCLUSION

This effort took on an unexpected turn due to the COVID-19 pandemic early during the period of performance. This turned out to be beneficial by increasing the total number, variety, and types of events that were conducted, while eventually completing the initial goal of six mock practical exercises. The variety of disasters, both real and simulated, included weather-related events (such as hurricanes, tornadoes, flooding, and landslides), man-made disasters (oil spills and train derailments), as well as wildfires, volcanic eruptions, and pandemic-related medical emergencies. Because of this variety, there is a rich harvest of observations and lessons learned that contribute to a better understanding of the issues posed by the research questions. The team has interwoven the findings and research questions within each event description in this report.

With the exception of FEMA, other federal agencies such as the United States Forest Service, and several State emergency response organizations, there is a substantial need for standardization of practices, training, qualification measurement, and organization. The FEMA Incident Command Structure, with its capacity to be expanded and contracted to meet the needs of a given event, would appear to be a valuable model for use by all first responders, regardless of how large or small their organization.

Further development is needed to establish a more formal definition of a body of regulatory standards, policies, procedures, and practices.

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# 8 APPENDIX A – LESSONS LEARNED REPORT

## 8.1 Overview

This task is to document and assess lessons learned from the exercises and demonstrations from Mock Event Demonstrations. The lessons learned were documented by the exercises with assessments during AAR with event participants, leadership, and first responders including operational pilots, regulatory agents, and the group that makes UAS response during disasters possible. In parallel with lessons learned, training conducted will be assessed by looking at tasks, conditions and standards for the future of first responder credentialing and training using the procedures and guidelines developed products. Lessons learned were collected using a standardized template developed from a modified FEMA After-Action Report template.

## 8.2 Lessons Learned Research Questions

1. What subset of use cases for the different disaster preparedness and response efforts are representative to demonstrate that UAS can help facilitate response?
2. How did the various agencies, responders, participants, and support personnel coordinate in the demonstrations and the lessons learned to ensure safe operations after a disaster?
3. What are the commons risks for the use cases and what are the mitigations to those risks to ensure safe operations for UAS?
4. What are the Concepts Of Operations (CONOPs) and Operational Risk Analysis (ORA) for the specific use cases identified?
5. What category of vehicles will work with each mission type?
6. What are the characteristics of the optimum UAS(s) for disaster preparedness?
7. What should future coordination with FEMA/DOI/DHS look like with UAS integrated into the NAS?
8. What are the considerations for secure Command And Control (C2) links?
9. What are the cyber security considerations?
10. What recommendations can be made for the refinement of requirements, technical standards, policies, procedures, guidelines and regulations needed to enable emergency response operations for use cases using UAS that increase effective, efficient, and safe use of UAS in a disaster?

## 8.3 Hurricane, Tornado, and Flooding Use Case (C.U.R.S.E)

### *8.3.1 Operations Overview:*

Purpose of this mission: In the wake of a powerful Category 4 hurricane making landfall near New Orleans, the affected region faces a multi-faceted disaster scenario. The hurricane unleashed destructive tornadoes, further exacerbating the damage to both the landscape and local communities. After the initial impact, extensive flooding has emerged as a persistent threat, continuing to disrupt surrounding areas. A severe lack of cell coverage complicated response efforts, necessitating the deployment of airborne communication resources to support and coordinate ground teams working diligently in these challenging conditions.

#### 8.3.1.1 Appropriate UAS Selection

*8.3.1.1.1 Key Findings:*

Teams arrived on mission sites without assessing task requirements. For example, during the first mission, the strike team acknowledged: "It worked out that the other crew did not take this mission. Their UAS would not have performed well." One team may have a better-suited UAS for the tasking.

*8.3.1.1.2 Recommendations:*

Before deploying for a mission, if there are multiple strike teams, it is recommended to communicate task requirements (data to be collected, area to observe, takeoff/landing locations if available, etc.). Strike team capabilities knowledge may also be observed from the Incident Commander, who would be able to assign tasks based on those capabilities.

*8.3.1.1.3 Informed Research Questions:*

This research investigated and informed how future coordination with federal entities, such as FEMA/DOI/DHS, may look like for UAS integration (see Question # 7).

#### 8.3.1.2 Multi-Crew Deconfliction

*8.3.1.2.1 Key Findings:*

Multiple crews were operating in one location at a time. The ASSURE team from UAH coordinated extensively with dozens of external crews to perform exercise tasks. This included deconflicting with other operators in the field. The extent of communication and deconfliction was not observed from other external crews operating during the exercise which led to some chaotic operations. Additionally, as new teams arrived on the scene, communication for deconflicting was non-existent.

*8.3.1.2.2 Recommendations*

It is recommended to designate a Visual Observer or other liaison to coordinate with crews on site. Being able to adjust as the situation progresses to accommodate other crews is essential. Therefore, having a plan in place before takeoff that explicitly assigned a Visual Observer, their responsibilities during the operation, and a means of communication between the pilot in command and visual observer would be beneficial. For example, the safety brief could include alternate routes or altitudes to fly, depending on additional operators in the area. This would also be beneficial if new arriving crews spread out so much that it becomes difficult to communicate.

*8.3.1.2.3 Informed Research Questions:*

This research investigated the federal response coordination of UAS operations and the cyber security of UAS data considerations (see questions # 7 and #9).

#### 8.3.1.3 UAS Familiarization

*8.3.1.3.1 Key Findings:*

There were instances observed when crewmembers may not have a complete understanding of the UAS being flown. Audible warnings for battery depletion were misinterpreted for Return to Home initialization.

*8.3.1.3.2 Recommendations:*

It is recommended to ensure the crew has been trained and is proficient with the UAS being operated. Currency requirements for organizations could ensure knowledge recency and proficiency levels are appropriate for the missions.

*8.3.1.3.3 Informed Research Questions:*

This research provided suggested details of Concepts of Operations (CONOPS) and Operational Risk Analysis (ORA) during various use cases (see Question # 4)

#### 8.3.1.4 GEO Fencing Locks

*8.3.1.4.1 Key Findings:*

One flight area required a custom unlock from DJI. This cannot be done from a phone, so it required the crew to utilize a laptop and go through the unlocking process.

*8.3.1.4.2 Recommendations:*

It is recommended to utilize DJI's Qualified Entities Program. This unlocks all no-fly zones in the United States. While this is reserved for public safety entities, those who support these entities on missions also qualify. This removes the requirement to receive a custom unlock and allows crews flying DJI equipment to get in the air much quicker. The crew will not have insight on the area of operations until the request comes through, so, having the UAS unlocked for all No Fly Zones (NFZ) locations would be ideal. It would also prove valuable to have a non-DJI UAS with similar capabilities on-site in case of NFZ issues. RPICs should keep in mind, that DJI unlocks do not replace an FAA airspace authorization, should one be required for the flight location.

*8.3.1.4.3 Informed Research Questions:*

This research addressed the considerations and challenges of UAS safety mechanisms, such as Geo fencing locks, details for CONOPS/ORAs, and ideal operational recommendations (see Questions #1, #4, and #6).

#### 8.3.1.5 Equipment Malfunctions

*8.3.1.5.1 Key Findings:*

Some crews had equipment overheating and had to either move to shade or pause operations to cool the equipment down. Ambient temperatures were in the 105-degree Fahrenheit range.

*8.3.1.5.2 Recommendations:*

Finding a spot to set up in the shade or pause operations to allow the equipment to cool down worked well for crews. Ideally, BVLOS approvals to allow the RPIC to operate from within a climate-controlled vehicle would be best. Bringing shade devices, fans, and ice coolers can also help in these situations. Before deployment, crews should consider the environment and how to best mitigate the environmental hazards to themselves and their equipment.

*8.3.1.5.3 Informed Research Questions:*

This research addressed the considerations and challenges of equipment malfunctions of UAS, for instance battery performance, details for CONOPS/ORAs, and ideal operational recommendations (see Questions #1, #4, and #6).

#### 8.3.1.6 Communication

*8.3.1.6.1 Key Findings:*

Due to the communication methods for this particular exercise, it was difficult for many crews to keep up with the assigned tasks. At least three separate means for communicating between crews and the EOC were established. These included the “Telegram” mobile application, e-mail, and cellular communications such as calling and text messages. Smaller crews especially did not have the resources to dedicate someone to monitoring these methods continuously, and it was easy to miss communications.

*8.3.1.6.2 Recommendations:*

It is recommended to simplify communication modes and limit communications to only pertinent information to improve communication pitfalls. The information necessary may include the location of the team, status of the task, and a situational report of the team performing the task. For example, the team lead should communicate when they arrive on site, when they are carrying out the task, when they have completed the task, and when they are ready for new tasking. However, in a real-world situation, electronic communications may be limited as a result of the disaster. The focus then would be on inter-crew communication procedures which should be addressed during the safety briefing with the crews.

*8.3.1.6.3 Informed Research Questions:*

This research provided recommendations on federal and team coordination as well as recommendations for procedural standards to communicate during UAS operations (see Questions #7 and #10).

#### 8.3.1.7 SGI/TFR Knowledge

*8.3.1.7.1 Key Findings:*

While nearly all crews operated under 14 CFR Part 107 during the exercise, it would be helpful for crews to become familiar with operations within TFR and how to procure SGI approvals from the FAA.

*8.3.1.7.2 Recommendations:*

Although SGI requests would not be approved for training scenarios, it would be beneficial for future training exercises to implement a mock “approval authority” for crews to run through the process. This would ensure that for real-world situations, crews would have the knowledge necessary to obtain emergency approvals.

*8.3.1.7.3 Informed Research Questions:*

This research suggested including operations within a TFR and the SGI process in CONOPS/ORAs (see Questions #4 and #10.

#### 8.3.1.8 Regulatory Knowledge

*8.3.1.8.1 Key Findings:*

Multiple crews were observed flying BVLOS of the RPIC. Some crews employed a VO in offset locations from the RPIC, under the impression that this would satisfy the requirements of 14 CFR

Part 107.31. One crew failed to use a VO at all and continued to operate BVLOS of the RPIC throughout the entire flight.

*8.3.1.8.2 Recommendations:*

Ensure all crews follow the regulations by completing standardized training and briefings before the operation. Explore all possible avenues for legal operations- SGI, public COA if possible, and operating under 14 CFR Part 107 waivers.

*8.3.1.8.3 Informed Research Questions:*

This research suggested standardizing UAS training for public safety involved in UAS operations and the requirement to maintain CONOPS/ORAs, institutional best practices, and regulatory knowledge in the context of operational qualifications (see questions #2, #3, #4, and #10).

### *8.3.2 Lessons Learned Summary*

In this live exercise, lessons emphasized the importance of matching UAS to tasks through better communication among teams and the EOC. Effective coordination among multiple UAS crews is crucial to avoid interference between strike teams and to ensure the UAS with the best capabilities is assigned to the tasks at hand. Comprehensive training and currency requirements are needed to prevent misinterpretations of assignments and responsibilities. Understanding of equipment limitations and planning for equipment cooling in hot environments is essential. Simplified communication methods and inter-crew communication are crucial for effective operations. Lastly, crews should be well-versed in the regulatory environment in which they are operating – 14 CFR Part 107 or Public COAs. Knowledge in obtaining SGI approvals and procedures for operations in TFR areas can greatly increase the safety of the NAS while adhering to the regulatory environment. Practice of these operations should incorporate mock approval processes for SGI and TFR access.

## 8.4 lUAS Pandemics Use Case

### *8.4.1 Operations Overview:*

Purpose of this mission: Amid a pandemic crisis, a remote rural community finds itself critically undersupplied, with no viable road access available. The only lifeline is through airborne transport, but even this option is hampered by adverse IFR conditions, rendering crewed flight systems inoperable. Additionally, the local river, typically a vital transportation route, is rendered unsafe due to thin ice and hazardous ice blocks.

#### 8.4.1.1 Weather Conditions

*8.4.1.1.1 Key Findings:*

Knowing the likelihood of conditions the night before flight operations allows the lead for operations to determine if there is potential for operations. This will ensure the optimal use of the flight crew to support flight operations. Should adverse weather exist the crew and ground teams can accomplish other activities rather than waiting until the weather conditions improve. This optimizes their time, especially if the conditions are known the day before and show no options for safe flights on the proposed flight date.

##### *8.4.1.1.2 Recommendations:*

It is recommended to track the weather forecast the evening before a flight. Evaluate weather from METAR and TAF, if available for site location. Request a spot forecast just before flight take-off and landing as well as along the route. Assess to cancel the flight if conditions indicate no sign of change. If conditions do show signs of change to support operations, perform assessments before the team deploys to the flight location.

##### *8.4.1.1.3 Informed Research Questions:*

This research suggested standardizing UAS training for public safety involved in UAS operations and the requirement to maintain CONOPS/ORAs, institutional best practices, and regulatory knowledge in the context of understanding weather briefings (see questions #2, #3, #4, and #10).

#### 8.4.1.2 Being Prepared to Fly

##### *8.4.1.2.1 Key Findings:*

Given the mission, there may be issues with the UAS proposed to support the flight operations and/or a different payload required. Ensuring that all available UAS are ready to operate (fueled up, batteries charged, payload checked) allows the flight team to adapt to the needs of operations and complete the mission as required. Also, providing the flight crew with a range of spare components that can be called up if needed is essential.

##### *8.4.1.2.2 Recommendations:*

Run through checklists for all UAS at deployment, not just the one that is going to support the operations. Ensure all equipment is ready for flight and fully operational.

##### *8.4.1.2.3 Informed Research Questions:*

This research addressed the common risks, CONOPS/ORA, vehicles with unique operational requirements, and the optimal use of different UAS (see Questions #3, #4, #5, and #6).

#### 8.4.1.3 Staying Ready

##### *8.4.1.3.1 Key Findings:*

Weather can cause delays as conditions prevent safe operations. Periodic weather checks should occur to check current conditions at take-off and landing as well as along the route. During weather delays, these gaps can be used to run through checks of the equipment and keep all team members up to date on the operational mission so that the team is ready to operate.

##### *8.4.1.3.2 Recommendations:*

Use downtime during the operational day to check equipment and review SOPs and CONOPs for the mission, the UAS, and their payloads. Ensure the team is ready to fly, when the conditions support safe operations, and the team is optimized to use weather windows to complete operations in NAS.

##### *8.4.1.3.3 Informed Research Questions:*

This research identified the need for operational readiness and preparedness (see Question #4).

#### 8.4.1.4 Staying in Contact

*8.4.1.4.1 Key Findings:*

Flight operations started with a briefing at the hangar location before the two ground control stations, crew, and ground teams deployed to their locations. At one airport, there was additional taxiway engineering work occurring that required contacting the local international airport operations to receive an escort across the engineering work to reach the GCS site. On the day of the proposed operations, the site lead contacted the airport to obtain access and was informed of prohibitive security issues. Access was eventually granted.

*8.4.1.4.2 Recommendations:*

Keep a database of names and numbers of all local facilities around the operations take-off, flight, and landing locations. Ensure that the operational site lead is aware of any local changes to the deployment route to the GCS site to ensure safe operations.

*8.4.1.4.3 Informed Research Questions:*

This research emphasized the need to maintain appropriate means of communications in a CONOPS/ORA (see Questions #3, #4, and #7).

#### 8.4.1.5 Situational Awareness

*8.4.1.5.1 Key Findings:*

During the day's operations, the flight conditions changed as the day progressed from the first brief to the originally planned flight time and beyond. All flight crew and ground team utilized websites, radio channels, and applications to determine the weather conditions at the take-off, in-route, and landing sites. The site lead for operations had their specific application and continued to use the same tool to assess the changing weather, using the METAR and TAF when available. In addition, they examined the weather conditions by looking at the sky and wind direction to determine the conditions in real-time.

*8.4.1.5.2 Recommendations:*

Ensure the site lead for operations is aware of condition changes so they can make informed decisions for go/no-go actions. Follow SOPs and CONOPs for decision-making processes to determine if flight operations will continue. Have specific sites/apps that flight crew use and include these in SOP and CONOPs so that comparable information can be reviewed by all crew members. Crew and ground teams also should assess weather conditions at the site for take-off and landing as these may be different from METAR and TAF, given the CGS could be distanced away from the airport where the METAR or TAF is provided.

*8.4.1.5.3 Informed Research Questions:*

This research investigated the information required to maintain situational awareness and perform safe operations as well as the need to incorporate means to access this information in a CONOPS/ORA (see Questions #2, #4, and #10).

#### 8.4.1.6 Checklist Conformity

*8.4.1.6.1 Key Findings:*

During the checklist of the UAS and payload, an issue with the FPV camera was found. This was resolved by the flight crew and ground team to ensure that the data feed provided a clear signal for the flight operations. The team followed the checklists using the OEM handbook, with confirmation by a second flight crew member. Team members with experience in flying the lUAS were able to resolve the issues and support the team to continue the pre-flight checks.

*8.4.1.6.2 Recommendations:*

Include a check of all components during a pre-flight checklist. Include members of the flight crew who have flown the UAS before as well as a flight crew member who have used the payloads onboard. Experienced team members should support the crew to effectively detect and mitigate any issues and ensure safe flight operations.

*8.4.1.6.3 Informed Research Questions:*

This research identified the requirement to maintain a checklist for operational best practices and to require the use of those checklist in a CONOPS/ORA (see Questions #3 and #4).

#### 8.4.1.7 Checklist Discipline

*8.4.1.7.1 Key Findings:*

While conducting checklists, pre-, during, and post-flight, the RPIC and SIC followed a checklist directly from the UAS handbook. One flight crew member performed the checks and a second confirmed. This was done at both the GCS as well the hand-off when the RPIC at one GCS read out the checklist and the RPIC at the second GCS confirmed that the checks were completed. Following the handbook checklists allowed the flight crews to resolve any issues, such as issued detected with the 900 MHz communications at the second GCS. Here, the crew did not progress with their checks until the issue had been resolved.

*8.4.1.7.2 Recommendations:*

Have detailed checklists. Follow them by the book and have a second crewmember confirm the checklist was completed and all is safe for flight. Follow the checklist, step-by-step, for all missions, irrespective of the experience and flight hours of the crew. Record that the checklists were completed.

*8.4.1.7.3 Informed Research Questions:*

This research recommended the emphasis of training with and operating with checklists to ensure best practices (see Questions #3 and #4).

#### 8.4.1.8 Communications Protocols

*8.4.1.8.1 Key Findings:*

During the exercise, there were two GCSs and a VO in a chase helicopter. This meant there needed to be clarification on the terminology to be used between the RPICs and the VO. The team determined FAI, ENN, and CHASE would be used as call signs between the separate groups. This ensured clear communication as to who was talking on the radios during flight checklists and flight operations. Around busy airports, it is essential to have clear call signs to minimize any confusion.

##### *8.4.1.8.2 Recommendations:*

Define all call signs before flights occur. Determine the call signs for the GCS and RPIC as well as the chase aircraft, if used. Include identifying these call signs in the SOP, CONOPs, and checklists, where necessary. Include this information in the first brief of the day and ensure any updates are passed along to all in-flight crew and ground team.

##### *8.4.1.8.3 Informed Research Questions:*

This research recommended that both technical means of communication ahead of operations (see Question #4).

#### 8.4.1.9 SOP Knowledge

##### *8.4.1.9.1 Key Findings:*

This exercise was to fly from a large international airport to a small, non-towered rural community airport and back. This larger airport was in Class D airspace. Therefore, when an issue was identified and for the safety of the flight, the mitigation plan was to return to the smaller non-towered airport for a landing. The CGS crew and ground team at the Class D airport stayed in place until the UAS landed at the rural airport to support this action plan, if needed. All crews were aware of the mitigation plan to ensure safe operations and to minimize the risk of flying the lUAS into the Class D busy airspace if the UAS was not operating properly.

##### *8.4.1.9.2 Recommendations:*

Ensure all crew and ground team are aware of risks to the mission and are briefed on action plans to mitigate any hazards to safe operations. Keep the ORA up to date and have all crew and ground teams aware of backups for safe operations and mission action plans.

##### *8.4.1.9.3 Informed Research Questions:*

This research suggested requiring institutional SOP knowledge to include as an operational qualification (see Questions #4 and #5).

#### 8.4.1.10 Optimal Flying Parameters

##### *8.4.1.10.1 Key Findings:*

Weather conditions, specifically cloud ceilings, can limit safe flight operations, especially when ensuring that the mission follows COA requirements and VLOS operations. Flights on the previous day had been weather-restricted in the allowable altitude. As such, there had been issues with the 900 MHz signal and the FPV feed to the GCS in command. Therefore, a decision was made to fly at higher altitude, weather and COA permitting. Here, the flight crews adapted their knowledge from previous flights, along with knowledge of SOP and allowable operations to ensure communications between UAS and GCS's.

##### *8.4.1.10.2 Recommendations:*

Ensure flight crews and ground teams are aware of allowances of flight altitude due to weather constraints (ceiling) and permissions (COA). Ensure that local knowledge can be adapted into flight operations while ensuring all SOPs are adhered to and checklists followed. Take note of previous flights along the same route and adapt the flight route, within constraints, to mitigate issues and ensure safe operations.

###### *8.4.1.10.3 Informed Research Questions:*

This research identified the requirement for aircrew to know and understand the necessary control settings and parameters for different UAS platforms and tasks (see Questions #3, #4, #5, #6, and #8).

### *8.4.2 Lessons Learned Summary*

It is critical to assess weather conditions well in advance of the operation and be ready to cancel flights if conditions are unfavorable. To enhance coordination, maintain a contact database to keep all stakeholders informed of mission adjustments. During operation postponements, conduct equipment checks and ensure the team is well-informed about mission constraints and modifications, optimizing readiness for favorable weather windows. Strict adherence to OEM and institutional checklists is essential at every stage of the operation. Lastly, emphasize clear communication with team members to ensure adherence to procedures and increase both safety and efficiency.

## 8.5 sUAS Pandemics Use Case

### *8.5.1 Operations Overview:*

Purpose of this mission: Amid an ongoing pandemic, a remote rural community is grappling with a severe shortage of critical supplies. Compounding their situation, no road access is available, leaving airborne transport as the sole viable option. However, the adverse IFR conditions have rendered crewed flight systems inoperative. To minimize the risk of further contagion, authorities are discouraging inter-community travel. Even the river that typically connects these communities is off-limits due to unsafe conditions.

### *8.5.2 Lessons Learned*

#### 8.5.2.1 UAS Issues

##### *8.5.2.1.1 Key Findings:*

While in flight, the RPIC noted issues via the hand controller of the UAS not working as it should. Using a handheld radio, the VO communicated to the RPIC the UAS was stable in air, but also noted visual issues with the gimbal. The RPIC decided to land the UAS near the VO's location. The RPIC was able to communicate to VO at the landing site to conduct a UAS calibration. The team was able to adapt to the issue and risk, build an action plan, assess the safety of the system, and once confirmed, safely continue the operation.

##### *8.5.2.1.2 Recommendations:*

Have all team members supporting the UAS operation be familiar with the UAS and train how to effectively communicate issues to RPIC. If able, include a team member on the mission who can fix or repair common issues.

##### *8.5.2.1.3 Informed Research Questions:*

This research addressed the need for aircraft familiarization and common risks as a necessary component to CONOPS/ORA, vehicle selection for tasks, and optimal use cases (see Questions #3, #4, #5, and #6).

#### 8.5.2.2 Weather Knowledge

*8.5.2.2.1 Key Findings:*

The local community RPIC and flight crew utilized a weather app on their phones to assess current and future weather conditions. This tool did not provide any available METAR or TAF nor did it determine visibility and cloud ceiling.

*8.5.2.2.2 Recommendations:*

Providing the RPIC with a list of weather sites and locations to obtain METAR and TAF, where available, as well as cloud conditions would ensure the most accurate weather data is available. Include weather check and briefing within checklists (pre-deployment to take-off and in pre-flight preparation).

*8.5.2.2.3 Informed Research Questions:*

This research suggested including weather briefing details and means to monitor weather conditions as an important component of a CONOPS/ORA (see Questions #3 and #4).

#### 8.5.2.3 Environmental Factors

*8.5.2.3.1 Key Findings:*

During a test flight, the RPIC and crew noticed that they were having issues with the compass on the UAS. This was causing it to fly erratically. It was noted that the power supply and generator on the roof of the hospital, near the take-off site could be the issue. The team was made aware of how this might cause issues and determined to move the take-off location away from the generator to mitigate the issue.

*8.5.2.3.2 Recommendations:*

Before flights, UAS crews should perform a comprehensive checklist and test all components of the UAS. Checks should include all major components of the UAS, compass, C2, navigation, etc., to ensure there is nothing near the take-off, flight route, and landing sites that could impact safe operations. Performing site survey tests before deployment will assist the team in determining a safe take-off and landing site and if there is a need to move away from other infrastructure that could limit operations.

*8.5.2.3.3 Informed Research Questions:*

This research investigated common risks of UAS operation from environmental factors, how those risks should be a component of CONOPS/ORA, and the appropriate selection of UAS platform or C2 technologies to maintain safe operations (see Questions #3, #4, #5, #6, and #8).

#### 8.5.2.4 UAS Registration

*8.5.2.4.1 Key Findings:*

The UAS to be used for this operation was newly acquired by the RPIC and the local drone club. Therefore, it needed to be registered with the FAA. The RPIC was instructed to obtain an FAA registration for the UAS. However, inaccurate information was provided to the RPIC on what is required to register the UAS and under what authority it should registered for the operation: 14 CFR Part 107 or recreational.

#### 8.5.2.4.2 *Recommendations:*

Ensure all operators are familiar with the FAA's DroneZone system and how to register new UAS within the system. Furthermore, a sound understanding of what constitutes a commercial vs. recreational flight is important. Incorporating a process flow document can help new users register a UAS for the first time.

#### 8.5.2.4.3 *Informed Research Questions:*

This research suggested the need for an understanding of registration regulations (see Question #10).

### 8.5.2.5 Recreational to Commercial

#### 8.5.2.5.1 *Key Findings:*

The local drone club conducting the operations was aware of the FAA's TRUST recreational certificate. The club utilized the recreational rules for many flights and served as a bridge to commercial operations.

#### 8.5.2.5.2 *Recommendations:*

Provide information on the TRUST recreational certificate to local clubs already working with UAS to provide a bridge to commercial operations. This can support their members to be safe pilots and progress to 14 CFR Part 107 certified.

#### 8.5.2.5.3 *Informed Research Questions:*

This research suggested the need for an understanding of recreational UAS operations in the context of training, CONOPS development, and regulatory knowledge (see Questions #4 and #10).

### 8.5.2.6 Hub and Spoke Operations

#### 8.5.2.6.1 *Key Findings:*

In the town of Bethel and similar places around rural Alaska, much of the community is a significant distance from the local hospital. Winter weather conditions, i.e., snow drifts, can prevent residents from getting to hospital or for emergency services to reach them. UAS could provide rapid support during the winter months. This type of CONOPs represents a need for a community like Bethel where small-scale hazards can significantly impact the safety of the community.

#### 8.5.2.6.2 *Recommendations:*

There are opportunities to build a database of scenarios where UAS could make a positive impact on the safety of local populations. CONOPs could be used in the advent of an event that would be helpful to support rapid response where certified pilots with UAS could support emergency services.

#### 8.5.2.6.3 *Informed Research Questions:*

This research investigated the use case of transportation between rural and more populated areas to include considerations on CONOPS, agency partnerships and coordination, application of various vehicles, and best practices (see Questions #1, #2, #4, #5, and #6).

#### 8.5.2.7 Weather Briefings

*8.5.2.7.1 Key Findings:*

A52 team members observing the operations conducted weather checks at approximately 13:00 and 15:00 LT (21:00 and 23:00 UTC) and noted the weather conditions indicated light rain in the vicinity as well as a low cloud ceiling (15:00 LT, 23:00 UTC METAR showed broken clouds at 500 ft). The RPIC and mentor started the pre-deployment briefing to inform all involved in the mission of the planned operations and the significance of their roles. Although the RPIC checked the weather, it was not briefed to the rest of the team. Given the conditions were near minimums, this was critical information.

*8.5.2.7.2 Recommendations:*

All crewmembers, especially the operational lead and/or the RPIC should include updated weather condition analysis in the pre-deployment and pre-flight checks. This information should be reported within the safety briefing before flights. If the weather is near minimums, the briefing should include what the minimums are and what happens if the weather drops below those minimums.

*8.5.2.7.3 Informed Research Questions:*

This research suggested common knowledge of weather briefings between all members of the aircrew to reduce operational risk and more informed CONOPS development (see Questions #3 and #4).

#### 8.5.2.8 Terminology

*8.5.2.8.1 Key Findings:*

During operations, some miscommunication was noted. The VOs were aware of the proper terminology to be used during operations, but failed to use it at all times. The RPIC had to remind the VOs to use the correct terminology.

*8.5.2.8.2 Recommendations:*

Training all crewmembers on proper terminology and how to make clear and concise calls is important. Improper calls can lead to confusion and risk the safety of flight.

*8.5.2.8.3 Informed Research Questions:*

This research suggested common terminology for UAS operations amongst aircrew members to reduce operational risk and more informed CONOPS development (see Questions #3 and #4).

#### 8.5.2.9 VO Placement

*8.5.2.9.1 Key Findings:*

The RPIC and VOs were stationed together on the roof of the hospital. Safety tape was used around the edges to help ensure safety. Tables, chairs, and small cones provided a sterile cockpit area for the RPIC and VOs.

*8.5.2.9.2 Recommendations:*

It is important to provide a sterile cockpit environment for the UAS crew. Establish a defined area and communicate to all non-essential personnel to remain outside the cockpit area and refrain from talking to the crew during flight unless they identify a safety of flight issue. Incorporate these practices into the SOP and CONOPs.

*8.5.2.9.3 Informed Research Questions:*

This research suggested emphasized the importance of VO placement to reduce operational risk (see Questions #3 and #4).

**8.5.2.10 RPIC Certification**

*8.5.2.10.1 Key Findings:*

The RPIC had completed the Unmanned Aircraft General exam required by the FAA for Part 107 certification. However, the individual failed to complete FAA Form 8710-13 for a remote pilot certificate through IACRA. The pilot was able to submit their IACRA application on the day of the final flights but was unable to receive a temporary certificate by the time the flight was underway. For these flights, the pilot assumed the role of person manipulating the controls, and a certificated RPIC stood next to them.

*8.5.2.10.2 Recommendations:*

RPICs should review FAA guidance on how to become certified under 14 CFR Part 107. The FAA has sufficient resources available online that enable operators to become certified. This is often an overlooked item, as many assume that upon passing the test, the FAA will send their certificate. As future local pilots are trained, it would be good to put emphasis on the steps the pilot should take post-test. This will prevent any barriers to operations.

*8.5.2.10.3 Informed Research Questions:*

This research emphasized the need for remote pilots to maintain certification and regulatory knowledge to reduce operational risk and as a component of CONOPS (see Questions #4 and #10).

**8.5.2.11 UAS Selection**

*8.5.2.11.1 Key Findings:*

The UAS was operated in light rain and misty conditions, as reported by the METAR. The OEM specifications do not indicate any ingress protection (IP Rating), nor do they offer insight into operations in an environment with moisture. A "positive pressure" argument was made for the UAS, but that did not prevent water from entering the motors or potential water from entering the battery compartment. While the likelihood of a single flight in this environment causing any damage to the electronics is minimal, continued operation within the environment could prove detrimental. Although 14 CFR Part 107 weather minimums impose a strict limitation, other UAS could be sought that handle moisture better in Alaska's weather.

*8.5.2.11.2 Recommendations:*

For any operational environment, research should be conducted for a UAS that can withstand the prominent conditions of the area. This can be used to secure a UAS that would allow delivery of goods in a broader environment. Standardized training or a minimum flight-hour requirement could be established for these operations to ensure pilots and their crews are familiar with the UAS being flown and the limitations associated with them.

#### *8.5.2.11.3 Informed Research Questions:*

This research provided suggestions on minimal training familiarization of UAS by aircrew for specific use cases or disaster response application (see Questions #1, #5, and #6).

### 8.5.2.12 Scenario Practice

#### *8.5.2.12.1 Key Findings:*

Although 14 CFR Part 107 allows for the carriage and delivery of goods within VLOS, this operation only simulated a delivery with no package being dropped. As local RPICs train to this scenario, it would be beneficial to actually deliver packages by carrying a payload on the UAS.

#### *8.5.2.12.2 Recommendations:*

Payload drop mechanisms can be purchased off the shelf for the UAS used on this flight as well as other commercial off-the-shelf UAS. Future training could include the carriage of a payload to deliver. This may change flight time, flight characteristics, and crew communication procedures. This shift would be more in line with real-world deliveries and would be a great stepping stone to flying packages at further distances outside of Part 107.

#### *8.5.2.12.3 Informed Research Questions:*

This research investigated the challenges in supply delivery and the need to practice or train on scenarios to ensure best practices and safe operations to include required training in CONOPS/ORA (see Questions #4, #5, and #6).

### *8.5.3 Lessons Learned Summary*

With remote areas, it is crucial for UAS teams to understand UAS systems and obtain basic maintenance training to address UAS issues. Advanced weather assessments may be required for pilots in the rapidly changing environmental conditions they face. Conducting a thorough weather review before each flight is essential, especially when local weather conditions may deviate from METAR and TAF data. Emphasizing clear communication, maintaining safe distances, ensuring regulatory compliance, and selecting suitable UAS models are key takeaways.

## 8.6 Train Derailment Use Case

### *8.6.1 Operations Overview*

Purpose of this mission: The objective of this event was to explore the use of UAS to provide an effective response to a train derailment scenario. Both fixed-wing and multirotor UAS were deployed for data collection and piloted by small teams from the various agencies involved. Coordination between multiple teams was carried out by a UAS ‘Air Boss.’

The scenario centering the exercise is as follows:

*“Vermont Agency of Transportation has been notified that a freight train derailed along the Burlington Vermont Waterfront near the Island Bike Trail. Information is limited as to the extent of damage to infrastructure, active fire, injuries of those directly or indirectly involved, missing persons, or hazardous materials or liquid leaking from the carts into the local environment. Vermont Agency of Transportation requests UAS support from local and state agency first responders and additional groups with UAS capabilities. Following local and federal regulations pertaining to UAS operations in controlled airspace, the UAS Air Boss must organize, manage,*

*and deploy multiple UAS assets to obtain unknown information, later to be dispersed to impacted stakeholders and investigating authorities."*

### *8.6.2 Lessons Learned*

#### 8.6.2.1 Incorporation of UAS Air Boss

*8.6.2.1.1 Key Findings:*

Ambiguity regarding the airflow control of aircraft caused unnecessary battery depletion. Air Boss could be clearer in communications when acknowledging calls from various UAS teams. Air Boss could benefit from having aerial data collection priorities. The Air Boss may better integrate UAS by having access to the UAS livestream to direct operations.

*8.6.2.1.2 Recommendations:*

Publish and share planned times of operation of each use case. Radio discipline, including standardized radio call procedures, can minimize confusion amongst operators, particularly when multiple UAS are operating at one time. Prioritize aerial data collection priorities. Establish a COP that shows the geographical location of all assets, including UAS. Incorporate video streams onto the COP, and make the COP available to the Air Boss.

*8.6.2.1.3 Informed Research Questions:*

This research investigated the challenges of low-altitude airspace coordination and the potential implementation of an "Air Boss" role in the context of different mission sets, multi-agency coordination, CONOPS/ORA, and cyber security (see Questions #1, #2, #4, #7, and #9).

#### 8.6.2.2 SAR Operations

*8.6.2.2.1 Key Findings:*

Flying a grid pattern proved more effective than flying point to point and slewing the sensor back and forth. Using a UAS with both imagery (video) and thermal is more effective than using only sensors with optical video capability.

*8.6.2.2.2 Recommendations:*

Establish a flight plan in a grid pattern and keep the sensor in a fixed downward position while searching. Utilize a UAS with both electro-optical and thermal sensors.

*8.6.2.2.3 Informed Research Questions:*

This research identified effective means to perform SAR with UAS in the context of to multi-agency coordination, CONOPS/ORA development, and operational best practices (see Questions #2, #3, #4, #5, and #6).

#### 8.6.2.3 UAS vs. UAS Deconfliction

*8.6.2.3.1 Key Findings:*

Separation of launch and landing zones for fixed-wing and multirotor UAS is recommended to reduce the complexity of airspace coordination. When conducting simultaneous UAS operations, each multirotor aircraft should have a dedicated launch/land pad. When flying multiple UAS operations, airspace deconfliction needs to be mitigated.

*8.6.2.3.2 Recommendations:*

Due to the variation in operations between fixed-wing and multirotor aircraft, establish separate areas for take-off and landing. During multi-UAS operations, establish a discreet take-off and landing pad for multirotors to enable simultaneous recoveries when necessary. Establish a plan for altitude separation when aircraft are operating in the same geographical proximity. When able, establishing discreet volumes of airspace can also promote separation of aircraft.

*8.6.2.3.3 Informed Research Questions:*

This research investigated deconfliction efforts between UAS teams and operational tasking in the context of multi-agency coordination, common operational risks, components of CONOP develop, and cyber security concerns (see Questions #2, #3, #4, and #9).

#### 8.6.2.4 UAS Aircraft and Sensor Selection

*8.6.2.4.1 Key Findings:*

UAS selection is driven by aircraft availability. In most cases, the appropriate UAS will be driven by the optimum sensor for the use case at hand.

*8.6.2.4.2 Recommendations:*

For SAR operations, using a UAS with both imagery (video) and thermal is more effective than using only sensors with optical video capability. Deployment of a 5+ band multispectral imaging sensor may provide situationally sufficient resolution in mapping imagery products to mitigate the need for a subsequent dedicated EO/true-color mapping mission.

*8.6.2.4.3 Informed Research Questions:*

This research performed an assessment of how difference UAS platforms and sensor payloads may apply to different disaster relief tasks to include how to incorporate equipment selection in a CONOPS and cybser security concerns (see Questions #4 and #9).

#### 8.6.2.5 Regulatory Knowledge

*8.6.2.5.1 Key Findings:*

While the crews demonstrated familiarity with operating the UAS, they were not fully aware of Part 107 regulations. In one use case, the RPICs and VOs did not maintain eyes on the aircraft, although it was within VLOS range at all times. At one point in scenario 2, they were asked where the aircraft was located, and it took them a while to physically establish visual contact.

*8.6.2.5.2 Recommendations:*

During the hotwash, the crews acknowledged they could use some help in strengthening their regulatory knowledge. Provide a one-page reference guide of Part 107 requirements to remind them of key guidance.

*8.6.2.5.3 Informed Research Questions:*

This research suggested that maintaining understanding of the rules and regulations that pertain to UAS operations is an important component towards ensuring safe operations (see Question #10).

### 8.6.3 Lessons Learned Summary

The integration of a UAS Air Boss created several lessons learned for future consideration. While there are efficiencies and increased safety factors with the implementation of this role, the importance of clear, standardized communications becomes paramount. It is also important for the Air Boss to understand aircraft/sensor capabilities, data collection priorities, and operating parameters.

The need for a UAS Air Boss is derived from the implications that there will be multiple UAS operations occurring near one another, sometimes in the same geographic boundaries. A strong vertical and horizontal deconfliction plan is imperative to promoting safe operations.

While some operations do not have the luxury of being selective in terms of optimal UAS and sensors for given use cases, wide-scale operations can help increase the likelihood of having relevant sensors for various applications. It is helpful for the tasking agency to understand which systems are available to meet aerial data collection requirements.

## 8.7 Wildland Fire Use Case

### 8.7.1 Operations Overview

Purpose of this mission: Following the detection of a new wildland fire via satellite data, emergency responders swiftly deploy UAS to assess and respond. UAS operations include:

- Mapping the landscape to guide first responder deployment.
- Mapping hotspots within the fire perimeter.
- Detecting smoke plumes for air quality monitoring and evacuation planning.
- Measuring vegetation health ahead of the fire spread to support fire modeling efforts.

This coordinated approach enables rapid response and effective mitigation of the wildfire's impact.

#### 8.7.1.1 Time to Produce Mapping Products

##### *8.7.1.1.1 Key Findings*

Mapping products can take significant time post-flight to produce so the EO, thermal, and LiDAR images are generally not available during/immediately after a flight. Some processing and stitching time for the images can take many hours. Many of the Trinity maps are between 2.5 and 4.5 cm per pixel which is excellent resolution for the forester’s applications (significant improvement compared to those they currently have access to).

##### *8.7.1.1.2 Recommendations*

If pre and post-mapping products are required, these need to be planned in advance to ensure products are available to the required stakeholders.

##### *8.7.1.1.3 Informed Research Questions:*

This research indicated the importance of understanding stakeholder needs ahead of flight operations to ensure task success, determine proper equipment selection, and identify specific rules/regulations that might pertain to the task (see Questions #6 and #10).

#### 8.7.1.2 Quality of Local Weather Data

##### *8.7.1.2.1 Key Findings*

Local weather predictions may not provide full insight into the local wind conditions. An example of this was demonstrated when the Trinity fixed wing aircraft took off. As it climbed up and before transitioning from vertical to forward flight, it weathervaned into the local wind direction. In one case, the winds aloft were at least 90 degrees out of alignment with the ground winds. The ground winds were aligned with the local forecast, but the winds aloft were not.

##### *8.7.1.2.2 Recommendations*

Launch teams, on initial launches of aircraft, especially for VTOL aircraft that will transition from vertical to forward flight, should be prepared that the flight direction may be different due to winds aloft. Vertical sampling of wind direction before flights could also be done to properly prepare for the transition phase of the flights.

##### *8.7.1.2.3 Informed Research Questions:*

This research identified the need for accurate weather briefing data to reduce operational risk and to determine the operational best practices for mission tasking (see Questions #3 and #6).

#### 8.7.1.3 UAS Operations Over the Active Fire

##### *8.7.1.3.1 Key Findings*

There are multiple potential limits on the operation of equipment near active fires. This can include the obvious exposure to high temperatures. During the active fire, the Skydio was attempting to follow a bulldozer movement at the request of the forester, and the aircraft was buffeted by thermals generated by the fire. At one point the smoke obscured the visual observation of the aircraft, the flight was immediately cancelled, and the aircraft was safely landed.

##### *8.7.1.3.2 Recommendations*

Establish specific operational protocols to enhance safety by ensuring aircraft visibility at all times and prevent overheating.

##### *8.7.1.3.3 Informed Research Questions:*

This research investigated the challenges of UAS operations over active fires in the context of risk assessment, CONOP development, and how different aircraft/sensor solutions may perform (see Questions #3, #4, and #6).

#### 8.7.1.4 Flight Altitudes for Optimal Support

##### *8.7.1.4.1 Key Findings*

Flight operations adhering to Part 107 with a maximum altitude limit of 400 ft AGL do not provide optimal support during fire operations. Example 1 – The Matrice EO and thermal images were invaluable during the operations. These helped the burn team make real time decisions on resources and response. It should be noted that operation of the Matrice below 400 ft AGL was not nearly as effective as operation of the aircraft at 500 ft to 600 ft AGL. The aircraft was buffeted by thermals at lower altitudes and the view angles to see the desired points as noted by the on-scene forester required higher flight altitudes. While the team had the proper approvals to legally and safely do this, these flight altitudes are not possible under Part 107 flights. Example 2 – The Super Volo also flew at much higher altitudes than the Part 107 limits. This aircraft can provide excellent wide area oversite coverage for many hours flying at 1,100 ft AGL with a camera that can be commanded on a target with excellent zoom and resolution. It more than adequately covered the entire burn area for this event. The coverage area can be adjusted real time to shift the focus of the targets.

##### *8.7.1.4.2 Recommendations*

Allow UAS to operate at optimal altitudes for the support even if they are higher than the Part 107 limitations.

##### *8.7.1.4.3 Informed Research Questions:*

This research investigated the use of various UAS platforms at different altitudes and determined the potential risk, CONOP considerations, operational best practices, and regulatory authorization for complex operations (see Questions #3, #4, #6, and #10).

#### 8.7.1.5 LiDAR Operation with Smoke

##### *8.7.1.5.1 Key Findings*

There was a question of how well the LiDAR would work with significant smoke present. While there is more processing to be completed and additional assessment of the products, the smoke on this fire, which was heavy at times, did appear to slightly impact the results. Some artifacts were in the air above the ground which are not real points, but overall, the LiDAR still performed excellent imaging even with smoke present.

##### *8.7.1.5.2 Recommendations*

Understand the limitations when using LiDAR if flying over dense smoke.

##### *8.7.1.5.3 Informed Research Questions:*

This research investigated the use case and limitations of Lidar for operations in smokey environments in the context of operational risk, best practices, and CONOP development (see Questions #3, #4, #5, and #6).

#### 8.7.1.6 People and Asset Identification During Burn Operations

##### *8.7.1.6.1 Key Findings*

The forester wanted to use the UAS to help identify bulldozer locations and locations of personnel during the burn. This was needed at one point when there was a fire jump at one location to move personnel who were on the far side of the burn. Smoke obscured easy identification of people and assets.

##### *8.7.1.6.2 Recommendations*

Add IR beacons with different unique signal signatures to the top of the bulldozers and safety helmets to aid individual identification of people and assets using the IR cameras on the drones.

##### *8.7.1.6.3 Informed Research Questions:*

This research investigated the application and limitation of UAS operations in burn scenarios in the context of multi-agency coordination, operational best practices, CONOP development, and regulatory considerations (see Questions #2, #3, #4, #6, and #10).

### *8.7.2 Lessons Learned Summary*

The processing and stitching time for EO, thermal, and LiDAR images can take many hours. If pre and post-mapping products are required, these need to be planned in advance to ensure products are available to the required stakeholders. Local weather predictions may not provide full insight into the local wind conditions. Vertical sampling of wind direction before flights should also be done to properly prepare for the transition phase of the flights.

There are limitations on the operation of equipment near active fires due to smoke and heat. To enhance safety, operational protocols must ensure aircraft visibility at all times and prevent overheating. Understand the limitations when using LiDAR if flying over dense smoke to avoid image artifacts. To aid individual identification of people and assets using the IR cameras on the drones, add IR beacons with different unique signal signatures to the top of the bulldozers and safety helmets. Allow UAS to operate at optimal altitudes for the support required even if they are higher altitudes than the Part 107 limitations.