A11L.UAS.68_A62: Disaster Preparedness and Emergency Response Phase III

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16. Abstract

The Alliance for System Safety of UAS through Research Excellence (ASSURE) explored the use of UAS in providing effective and efficient responses to a variety of disaster scenarios. This third phase of the Disaster Preparedness and Response research tasks included the investigation into challenges and solutions to multi-agency coordination, technical standards, regulatory needs, and data management. In this Final Report, the research team presents the background for the research performed, the technical solutions identified to enable expanded operations, the use cases and operational characteristics for a range of disaster categories, considerations of existing regulatory and legislative standards, and data sharing requirements. The technical research tasks in these areas are complimented by extensive reporting on real-world use cases and operational exercises performed by the ASSURE research institutions during the period of performance of this program. The observations, lessons learned, and recommendations are included in this Final Report.

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3D	Three Dimensional
AGL	Above Ground Level
AGOL	ArcGIS Online
AI	Artificial Intelligence
AOBD	Air Operations Branch Director
ASSURE	Alliance for System Safety of UAS through Research Excellence
ASTM	American Society for Testing and Materials
ATAK	Android Team Awareness Kit
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CFR	Code of Federal Regulations
COA	Certificate of Authorization
COE	Center of Excellence
CONOP	Concept of Operations
COP	Common Operating Picture
CORS	Continuously Operating Reference Station
COT	Commercial Off The Shelf
DHS	Department of Homeland Security
DOI	Department of Interior
DAART	Domestic Operations Awareness and Assessment Tool
EO	Electro-Optical
EOC	Emergency Operations Center
ESRI	Environmental Systems Research Institute, Inc.
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GRS	Geographic Response Survey
ICS	Incident Command System
IMS	Integrated Master Schedule
IMU	Inertial Measurement Unit
IR	Infrared
LiDAR	Light Detection and Ranging
mph	Miles Per Hour
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCEI	National Centers for Environmental Information
NCSU	North Carolina State University
NDAA	National Defense Authorization Act
NIST	National Institute for Standards and Technology
NMSU	New Mexico State University
NWCG	National Wildfire Coordination Group
OOP	Operations Over People
PII	Personally Identifiable Information
PMR	Program Management Review
POP	Period Of Performance

PPK	Post Processing Kinematics
RID	Remote Identification
RTK	Real-Time Kinematics
RTP	Research Task Plan
SARCOP	Search and Rescue Common Operating Picture
SGI	Special Governmental Interest
SOSC	System Operations Support Center
sUAS	Small Uncrewed Aircraft System
TAK	Team Awareness Kit
TFR	Temporary Flight Restriction
TIM	Technical Interchange Meeting
UAH	University of Alabama in Huntsville
UAS	Unmanned Aircraft System
UTM	UAS Traffic Management
UV	Ultraviolet
UVM	University of Vermont
VCGI	Vermont Center for Geographic Information
VLOS	Visual Line of Sight

EXECUTIVE SUMMARY

The third phase of the long-term ASSURE Disaster Preparedness and Response research program began in October 2022 and ended in February 2025, exploring the use of UAS as an effective and efficient tool to support response efforts in a variety of disaster scenarios. As part of a continuation from two previous phases of ASSURE research, A62-Phase III identified technology solutions to enable expanded operations, use cases, and operational characteristics for a wide range of disaster categories, considerations of existing regulatory and legislative standards, and data management challenges. Research and operators from five ASSURE COE partner institutions conducted research in these technical areas and fostered relationships with local, state, regional, and federal public safety entities to guide valuable insights.

In this Final Report, the research team presents the findings and insights from technical research tasks and complements these results through extensive engagement in real-world response efforts and operational exercises during this program's performance period.

1 INTRODUCTION & BACKGROUND

This document serves as the final report for *A11L.UAS.68: Disaster Preparedness and Emergency Response Phase III*, hereinafter referred to as A62, the third phase of a long-term research program focused on exploring the use of Unmanned Aircraft Systems (UAS) in disaster response and recovery. The Alliance for System Safety of UAS through Research Excellence (ASSURE) coordinated this phase and the previous phases of this program as the Federal Aviation Administration (FAA) Center of Excellence for UAS (COE), which is a consortium of thirty universities and more than a hundred leading industry and government partners based out of the Mississippi State University. Led by the expertise and experience of ASSURE, the University of Alabama in Huntsville (UAH) directed the overall A62 team project as the principal investigator with research partners from New Mexico State University (NMSU), University of Vermont (UVM), North Carolina State University (NCSU), and Kansas State University (KSU). These universities have demonstrated extensive research capabilities and operational conduct across natural and human-made disasters and emergencies using UAS as well as expertise in the technology employed during disaster response and recovery. Under this program, the ASSURE COE and partner institutions sought to maximize interagency coordination of A62, and other ASSURE programs, by working closely with federal agencies responsible for emergency management including the Department of Homeland Security (DHS), Department of Interior (DOI), and respective regional, state, and local public safety agencies.

A62 was the third phase of Disaster Preparedness and Emergency Response research programs from the ASSURE COE. Following on from the results, findings, and lessons learned from A28/Phase I which ran from FY20-FY22, and A52/Phase II from FY21-FY23. The first phase of this long-term research effort examined how UAS have been used in emergency response scenarios. This research was conducted through surveys and public safety community engagement over several months focusing on first responder experience with UAS, concerns about adopting UAS based on regulatory barriers, and the challenges in operational risk management. This phase guided the ASSURE COE research team into the second phase, A52, which continued to evaluate the role of UAS and supporting technologies, such as Geographic Information Systems (GIS) and UAS Traffic Management (UTM) solutions, through the development of demonstrations, workshops, and functional exercises. The geographic distribution of the partner institutions on the A52 research team allowed each university to develop and host these events on specific disaster categories relevant to their region. For instance, UAH hosted events focused on hurricanes and tornados while the University of Alaska Fairbanks hosted events on oil spills and rural medical delivery. A52 underscored the importance of functional exercises where both researchers and public safety agencies can interact and simulate real-world events in preparation for response and recovery deployments. This phase led to the concept of "minimum operational proficiency standards" and a document reflecting the 14 Code of Federal Regulations (CFR) Part 107 rules and regulations on commercial UAS operations in the National Airspace System (NAS) geared towards public safety operators which was called the "Beyond Part 107" document.

The continuation into Phase III, or A62, emphasized the research focus to refine regulatory structures for disaster-specific guidelines by engaging with the public safety community on a local, state, regional, and federal level through exercises. However, an additional requirement for A62 was also made to conduct targeted research into technology solutions. Identification and evaluation of technology solutions to enable expanded operations that are coming from other sectors of the UAS market or are only emerging into the public safety sector was a key research objective of the third phase. Identifying additional use cases and the operational characteristics of more disaster scenarios was also embedded in the research tasks and driven by specific research questions proposed to the ASSURE COE research team. The overall research questions established by the ASSURE COE team for A62 are listed below along with the research task-specific questions that were addressed.

- What are the use cases for the different disaster preparedness and emergency response efforts that UAS can help facilitate?
- How is coordination done today at the local, state, and federal (e.g., DOI and DHS) levels to ensure safe operations after a disaster or emergency?
- What are the common risks for the use cases? What are the mitigations to those risks to ensure safe operations for UAS?
- What are the Concepts of Operations and Operational Risk Assessments for the specific use cases identified? What category of assets will work with each mission type? What are the characteristics of the optimum UAS(s) for disaster preparedness and emergency response?
- What lessons were learned from the use case demonstrations?
- What should future coordination at the local, state, and federal (e.g., DOI and DHS) levels look like with UAS integrated into the NAS?
- What are the Command and Control (C2) and cybersecurity considerations?

The A62 research tasks into technological solutions to enable expanded UAS operations support disaster response and recovery missions were predominantly driven by the following research questions:

- How could UAS supporting disaster relief efforts be expanded (including post-disaster recovery activities)?
- What are additional technology solutions that could enable expanded operations such as Beyond Visual Line Of Sight (BVLOS) disaster and emergency response and recovery UAS operations?
- What are the technological solutions to address the "common operating picture" for all agencies utilizing UAS during a response or recovery mission?
- What is the role of automation and/or autonomy in UAS supporting disaster and emergency response and recovery missions?

The research team was also challenged with assessing the potential use of UAS in additional use cases and to identify the operational characteristics based known applications of UAS in disaster response and recovery mission sets. This research task was guided by the following research questions posed to the ASSURE COE:

- What are additional use cases that should be explored for UAS supporting disaster and emergency response, recovery, mitigation, and situational awareness missions, including international use cases?

- What are the operational characteristics and requirements for multi-UAS operations supporting disaster and emergency response and recovery missions?
- What are additional use cases for UAS supporting future health pandemic response operations?
- What category of UAS platforms will work with each additional mission type? What are the characteristics of the optimum UAS(s) for disaster preparedness?
- What lessons were learned from the previous use case demonstrations?
- Where would UAS not be optimal for use during disasters and emergencies (i.e., manned aircraft may be more efficient at long-range response operations)?
- What are the risks and safety mitigations associated with UAS supporting a wide variety of disaster and emergency response use cases? What are the risks associated with the implementation of resulting recommendations by disaster and emergency response organizations?

The assessment of new legislation, policies, procedures, and standards on the UAS market at large and, more specifically, on government entities involved in public safety operations, was a research task aimed at defining the current or future UAS landscape. The potential adoptability of UAS and supporting technologies for public safety operators as well as barriers or challenges to establishing UAS programs were assessed in this research effort. The driving research questions guiding this research task were:

- What are the impacts of new legislation (such as the National Defense Authorization Act (NDAA) on local, state, and federal agencies using UAS for disaster and emergency response and recovery missions? What should compliance with this new legislation look like?
- What are the benefits and impacts of a public safety pilot rating beyond the Part 107 remote pilot rating?
- What should the additional airworthiness qualifications and crew training procedures look like for disaster and emergency response and recovery UAS operations? Are there any other policies and procedures that need to be developed to expand UAS supporting disaster and emergency response and recovery missions?
- How can UAS incursions during response and recovery missions be mitigated?
- How can disaster and emergency action plans for UAS supporting response and recovery be standardized across local, state, and federal agencies?
- Investigate the UAS fleet mix of local, state, and federal disaster and emergency response organizations, and determine the priority of policies and procedures for the future growth of fleets from organizations.
- Coordinate with the Federal Emergency Management Agency (FEMA) and National Wildfire Coordinating Group (NWCG) to determine what UAS typing standards would look like.
- How can concerns be mitigated regarding the issuance of Special Government Interests (SGIs)? Look at FEMA's processes regarding an Air Ops liaison.

In addition to the previously described evaluation of technological solutions enabling expanded UAS operations, a targeted research task into data sharing and storage considerations was also embedded in the A62 research tasks. While operational requirements involving the safe and effective flight of UAS are still a revolving challenge in disaster response and recovery, significant challenges exist with how public safety agencies collect, process, analyze, report, store, and share the immense amount of data collected during response and recovery operations. Research to evaluate these mechanisms to address the data needs were guided by the following research questions:

- What would the requirements and implementation look like for a centralized interagency data portal to streamline cross-governmental coordination? What data sharing and storing principles can be incorporated that are currently practiced by federal agencies, such as the Domestic Operations Awareness and Assessment Response Tool (DAART) utilized by FEMA Region 4?
- What are the cybersecurity risks associated with UAS supporting disaster and emergency response operations?
- Determine the requirements for a central database of UAS system and sensor capabilities, taking into consideration airworthiness and encryption factors. These capabilities should be based on standard test methods. Platforms should be vetted by real-world practitioners in the disaster and emergency response domain. An agency should be identified to host and maintain this database.
- What metrics should be created for the use of UAS during disasters and emergencies? Examples include: Acquisition, maintenance, and operation costs, percentage of UAS in aircraft fleet, number of UAS operations (by type of disaster), number of vehicle failures per platform during disaster response operations, number of operational failures per platform during disaster response operations, effective time of UAS operations (from planning to data delivery), frequency/tempo of UAS operations in an impacted area, number and density of UAS operations in an impacted area, etc.

Continuing the engagement of the ASSURE COE research team with public safety entities and the UAS community was also a key objective in A62. The emphasis to conduct domestic and international outreach to expand the scope and scale of research efforts through ongoing activities, including flight test scenarios and functional exercises throughout the period of performance of A62 was directly tasked to the research team and generally guided by the following research questions:

- How can outreach be expanded to enable/increase UAS international harmonization across the globe for disaster and emergency response?
- What lessons can be leveraged from the international disaster and emergency response and recovery community to improve domestic coordination processes and procedures?

The remainder of this final report document outlines the research task plan including program management, technical research tasks results and findings, and the impact of ongoing community outreach by the ASSURE COE research team. With the main objective of A62 being the development of frameworks, draft policies, and guidelines to help inform and coordinate expanded operations of UAS in the disaster response and recovery landscape, a fourth phase continuation of this long-term research program, called A84, began in November 2024 and builds on the efforts from the previous three phases.

2 RESEARCH TASK

The total Period Of Performance (POP) of the A62 Phase III program was twenty-eight (28) months starting in October 2022 and ending in February 2025. "Task 0" for A62 is known as the Program Management task which outlines general requirements for effective management of the program during the POP. **Sub-Task**s for Task 0 detail various aspects of the program that reflect the procedural meeting and reporting of other ASSURE programs. For example, the Kickoff Meeting once the program has started (***Sub-Task*** *0-1*), Research Task Plan development (***Sub-Task*** *0-2*), regularly scheduled Technical Interchange Meetings (TIM) (***Sub-Task*** *0-3*), FAA Leadership Briefings (***Sub-Task*** *-4*), and Project Closeout (***Sub-Task*** *0-5*).

Due to the revolving research approach for ASSURE Disaster Preparedness and Emergency Response, each subsequent phase of these programs is informed by and designed as follow-on tasks from previous phases. Phase I known as A28 sought to provide insight from the ASSURE consortium into how UAS can aid in disaster preparedness and response by investigating coordination procedures within various federal, state, and local emergency management agencies. The results from A28 are used to help develop technical standards, policies, procedures, and regulatory guidance needed for enabling emergency response efforts with UAS. The follow-on Phase II program, known as A52, built on the results and documentation from Phase I to emphasize the development of Concepts of Operations (CONOP) and procedures for coordination of UAS in a wide range of natural disasters and emergencies. Finally, the A62 Phase III program continues the trend of using the technical and regulatory needs for public safety UAS operations and the detailed CONOP from a variety of scenarios from the previous two phases to conduct long-term research efforts into four technical research areas and implement the CONOP documentation into real-world use cases. Sections 2.1.2 through 2.1.5 describe the technical research tasks and reference the completed Task Final Reports found in the Appendix of this document. These final reports are authored by the lead institution that performed the research detailing the proposed by the ASSURE consortium, the Sub-Tasks of specific research areas, the work completed, and the results from that research.

2.1 Research Tasks

2.1.1 Task 1: Review of Phase I and Phase II Findings, Recommendations, and Lessons Learned

A62 was a follow-on research program from two previous Disaster Response and Recovery research programs sponsored by the FAA. The first task of follow-on ASSURE Research Programs is a review of the work completed and lessons learned from past performance ASSURE programs to guide the research questions, technical tasks, and practical flight activities for Phase III. This review culminated in a Research Task Plan (RTP) to be completed within the first six months of A62 Phase III along with several ongoing tasks. UAH prepared an Integrated Master Schedule (IMS) using Microsoft Project as a framework to approach research tasks and practical flight activity progress to manage the timeline of the project. This IMS was updated monthly after receiving ongoing updates during TIMs. Other ongoing sub-tasks from Task 1 included the engagement of partner institutions with the public safety and research community to help recommend policy and propose procedural best practices for UAS in disaster response and recovery operations. Mid-cycle assessments, referred to as Peer Reviews in this program, were also carried out with various agencies to review and assess findings or possibly redirect efforts as needed. The organization of the RTP for subsequent tasks is outlined in Sections 2.1.2-2.1.6 for technical tasks as well as Sections 3.1-3.3 for outreach and practical flight events of this Final Report document. The RTP is a culmination of the IMS, Task Final Reports, and updates from TIMs during the POP of A62.

2.1.2 Task 2: Identification and Analysis of Technological Solutions to Enable Expanded Operations

Researching technological solutions to expand the operational capabilities of UAS, remote pilots, first responders, and emergency management coordination was the key focus of Task 2. The ASSURE team leading this task dedicated research efforts to four technology areas, specifically: (1) Operations of Multiple UAS (Swarms); (2) Remote Identification; (3) Technology Enabled Situational Awareness; and (4) Automated Air Boss. A Sub-Task for each of these technology areas included a detailed literature review and technical assessment of the current landscape of these technologies and their applicability in the context of emergency management. **Please Refer to Appendix A for a complete report of Task 2 research activities and results.**

Sub-Task Research Areas: Research efforts in Task 2 were divided into four Sub-Tasks meant to address specific research questions from the A62 Phase III proposal.

Table 1. Task 2 Technical Research Sub-Tasks.

Sub-Task Title	Research Question(s) Addressed
Operations of Multiple UAS (Swarms)	What is the role of automation/autonomy in UAS supporting emergency response and recovery missions?
Remote Identification	What services would a software solution need to enhance situational awareness for emergency responders?
Technology-Enabled Situational Awareness	What are the technical solutions to address the “common operating picture” for all agencies utilizing UAS during response and recovery missions? What Services would a software solution need to enhance situational awareness for emergency responders?
Automated Air Boss	What is the role of automation/autonomy in UAS supporting emergency response and recovery missions? What mechanisms can be put in place to enhance situational awareness for emergency responders, sterilize the area of an emergency, and alert responders to nearby UAS operations?

Task Findings and Results:

Sub-Task 2-1: This study identified the current technical capabilities, trends, and potential applications in disaster response and recovery for operations of multiple small UAS, or swarms. Extensive technological development in navigation and decision-making for autonomous ground and air vehicles is moving incident response tasks and coordinating multiple aircraft without direct human intervention is possible.

Formation management and geographic coverage algorithms used in navigation and decision-making can be trained to perform search patterns or surveillance and are adjustable based on real-time data ingest or by human intervention based on incident command priorities.

Sub-Task 2-2: This Sub-Task focused on researching the effectiveness of Remote Identification (RID) for UTM and distinguishing authorized versus unauthorized UAS for reducing operational risk in incident response efforts. The absence of rapid vehicle identification through RID makes it challenging to maintain situational awareness of uncrewed systems and poses a risk to authorized UAS operators and manned aviation operations in restricted and congested airspace often experienced in disaster response. Counter-UAS technologies are useful in detecting and monitoring aircraft but mitigation of unauthorized vehicles or threats may also pose a risk to authorized UAS, other airborne resources, and communication assets. An architecture framework and technical recommendations for managing RID within the National Aeronautics and Space Administration (NASA) UTM system using Flight Information Management System, UAS Service Suppliers, and vehicle registrations (14 CFR Part 47) represents a comprehensive implantation plan.

Sub-Task 2-3: A market survey and literature review were conducted to identify common services and traits of existing software suites used in military and emergency management. These services were aligned with the six major functions of the Incident Command System (ICS) and further defined based on UAS applications in disaster response efforts. Situational awareness and information sharing are extremely important and intensive tasks in emergency management regardless of the scale/scope of an incident. The disaster zone can quickly become a chaotic environment when multiple teams/agencies are mobilized for both ground and airborne activities. GIS represents a common foundation across all of the situational awareness tools that were assessed for disaster and emergency response.

- Search and Rescue Common Operational Platform (SARCOP)
- Android Team Awareness Kit (ATAK)
- CALTOPO/SARTOPO

Large-scale data aggregation and effective interpretation is a consistent challenge to establish a comprehensive understanding of the conditions, expectations, and prioritization of resource allocation but is a key function of a tool to enable a Common Operating Picture (COP).

Sub-Task 2-4: This task consisted of analyzing the key duties of airborne coordination within the Operations Section of ICS, specifically the Air Operations Branch Director (AOBD), and the expected functions of UAS operators in the field to identify what services an "Automated Air Boss" must provide. Automated Air Boss as a concept seeks to reduce the various responsibilities of an AOBD on certain air operations coordination by implementing automation. Developments in situational awareness tools and AI using large language models to generate text requests is a potential niche for automation in the air ops decision-making tree accommodating demand of air resource requests. Generating and submitting SGI and Low-Altitude Authorization Notification Capability requests, as well as Notice to Air Missions on behalf of remote pilots in command expediting approval. Integration of an Automated Air Boss with technology-enabled, data-driven situational awareness tools may increase efficiency for coordination, and deconfliction, and reduce direct human intervention There is a strictly defined hierarchy of ICS decision making for all scales of emergency management. Increased automation and technology solutions must function in accordance with this hierarchy to become an adoptable, effective tool enabling expanded and complex UAS operations.

2.1.3 Task 3: Identification and Analysis of Additional Use Cases and Operational Characteristics

Task 3 focused on identifying and analyzing additional use cases and operational characteristics of UAS for disaster and emergency response and recovery missions. This task involved examining various scenarios where UAS may aid responders in meeting the needs of an emergency or disaster scenario, extending beyond the US and exploring international contexts. This task addressed questions regarding UAS deployment for disasters, pandemic response, and other use cases. It also evaluated numerous mission types and use cases, exploring multi-UAS operations and lessons learned from past demonstrations. It also explored instances in which UAS may or may not be ideal for responders when responding to an emergency. **Please Refer to Appendix B for a complete report of Task 3 research activities and results.**

Sub-Task Research Areas: Task 3 consisted of seven sub-tasks, each exploring different aspects of UAS use cases, operations characteristics, and disaster response and recovery applications.

Table 2. Task 3 Technical Research Sub-Tasks.

Sub-Task Title	Research Question(s) Addressed
Additional Use Cases for UAS in Disaster Response and Recovery	What are additional use cases that should be explored for UAS supporting disaster and emergency response, recovery, mitigation, and situational awareness missions, including international use cases?
Characteristics and Requirements for Multi-UAS Operations	What are the operational characteristics and requirements for multi-UAS operations supporting disaster and emergency response and recovery missions?
Pandemic Response Applications	What are additional use cases for UAS supporting future health pandemic response operations?
Optimal UAS for Disaster Preparedness and Response	What category of UAS platforms will work with each additional mission type? What are the characteristics of the optimum UAS(s) for disaster preparedness?

Analysis of Lessons Learned	What lessons were learned from the previous use case demonstrations?
Non-Optimal Use Cases for UAS	Where would UAS not be optimal for use during disasters and emergencies (i.e., manned aircraft may be more efficient at long-range response operations)?
Risk and Safety Measures	What are the risks and safety mitigations associated with UAS supporting various disaster and emergency response use cases? What are the risks associated with the implementation of resulting recommendations by disaster and emergency response organizations?

Task Findings and Results:

Sub-Task 3-1: The research team identified additional use cases spread across four unique types of disasters: natural, anthropogenic, disaster and emergency response support, and other response operations. Table 3 shows the number of unique use cases associated with each type of disaster.

Table 3. Summary of Additional Use Cases.

Disaster Type	**Number of Use Cases**
Natural Disaster	12
Anthropogenic Disaster	23
Disaster Response Support	19
Other Response Operations	3

Based on the findings, there are at least 57 additional use cases for UAS in disaster response and recovery to explore. **Please refer to Appendix B, Section 2.1** for detailed descriptions of each use case identified and a brief overview of the applicable UAS, sensors, and operational considerations from this study.

Sub-Task 3-2: This study identified requirements for multi-UAS operations supporting disaster response and recovery. This task emphasized the need to operate multiple UAS within a disaster area to support responders. This task did not emphasize the 1:n – i.e., “one to many” operational construct for UAS. Instead, it focused on mitigating risks associated with “crowded airspace” during high-tempo disaster response operations where multiple entities supporting the response effort may operate different UAS. Findings from this task focused on the need for robust communication, coordination, and deconfliction systems that allow air traffic types to share common airspace blocks.

Findings from Task 3.2 highlighted the importance of UTM systems, shared data and communication, and COPs to provide situational awareness in disaster scenarios. Mitigating the risks associated with many users sharing a block of airspace for different missions requires all users to communicate, share crucial information – e.g., location, altitude, and flight plan- and deconflict in real time to maintain safety. An air boss may use tools like a COP to coordinate between UAS operators, conventional air assets, and other entities in the airspace to maintain safety and ensure operational goals are achieved.

Sub-Task 3-3: This study addressed health services and pandemic response cases for UAS. These use cases became increasingly relevant with the worldwide SARS-COV-2 epidemic in 2020 and subsequent years of interrupted supply chain challenges. They showed a need for UAS use cases to address public health services, logistics, and communications. The most apparent use cases are summarized here but **more details may be found in Appendix B, Section 2.3**.

UAS may be used for area disinfection missions, following a similar pattern to an agricultural sprayer. This use case allows UAS to apply disinfectant to larger, open-air areas. However, there are challenges with wind drift and filling gaps in surfaces and buildings. UAS may also be used for Ultraviolet (UV) sanitization, using UV light to kill bacteria and microbes across large outdoor areas.

Healthcare logistics represents another critical use case for UAS. Healthcare logistics networks can become strained in pandemic scenarios, especially when supplies are in critical demand. UAS can deliver supplies, such as vaccines, blood, and personal protective equipment, between locations quickly and efficiently.

UAS may also serve in the role of social monitoring and logistics during pandemic situations. Remote sensing methods and thermal Infrared (IR) sensors may allow them to detect heart rates, temperatures, and people expressing symptoms within a crowd. These capabilities may enable responders to screen large numbers of people quickly for isolation and quarantine.

Finally, UAS may serve in a communications role when supporting pandemic response. One-way loudspeaker attachments may allow them to broadcast messages to the public, allowing critical and time-sensitive messages to be delivered to large crowds. They may also provide quick response codes and other forms of messaging to aid responders in delivering critical information.

Sub-Task 3-4: This sub-task explored the pairing of UAS platforms, performance capabilities, and sensors to disaster types to identify UAS that are ideal for each mission type and characteristics of UAS and sensors that may achieve the best outcomes. Table 4 provides some general examples of operational use cases and technology pairings. **For more detailed results, please refer to the report found in Appendix B, Section 2.4.1 for additional examples of technology capabilities and Section 2.4.2 for a summary of the potential cyber vulnerabilities of technologies**.

Table 4. Findings from Task 3, Sub-Task 3-4.

Natural Disasters							
Event	**UAS**	**Sensor(s)**	**Function**				
			Mapping	**Live Feed**	**Sensor**	**Delivery**	**Comms**
Avalanche	Unknown (Rotary)	Thermal and RGB		X			
Biological Incidents	Rotary or Fixed-Wing	Thermal and RGB	X	X			
Dust Storm	3DR Solo (Rotary)	Pressure Sensor and RGB		X	X		
Drought	DJI M600 Pro UAS (Rotary)	Multispectral and Thermal	X				
Flooding	Various Rotary and Fixed-Wing	RGB	X	X		X	

Sub-Task 3-5: This sub-task captured lessons learned from previous demonstrations of disaster response using UAS. Findings for this task are captured in a "lessons learned" report from the previous phase of ASSURE Disaster Response and Recovery research, A52. Critical lessons and operational nuances associated with implementing UAS for disaster response are detailed in the ASSURE A52 Final Report, found at the following link: https://www.assureuas.org/wp-content/uploads/2021/06/A52-Final-Report-V13_FINAL.pdf.

Sub-Task 3-6: This Sub-Task served as a point of contrast to Sub-Task 3.4. While Sub-Task 3.4 identified optimal UAS for given disaster response scenarios, findings from this Sub-Task identified instances when UAS may not be optimal for responders. Findings indicate that employing UAS is based mainly on ensuring one employs the "right tool for the right job," tailoring UAS characteristics to the mission. This finding agrees with the concepts explored in Sub-Task 3.4. However, findings also indicate that employing UAS for disaster response and recovery may be limited by other factors, such as weather, UAS performance characteristics – e.g., endurance and other operating requirements – and regulatory, societal, and cultural considerations. Responders must factor the UAS they intend to employ, its performance, environmental concerns, and regulatory and societal constructs into their pre-mission deployment calculus.

Sub-Task 3-7: Finally, Sub-Task 3.7 explored additional risks and safety mitigations associated with various UAS response operations. Findings indicate a significant number of risks and an equally significant number of mitigations that are unique to multiple disaster scenarios. This study also explored the implications of adopting specific risk mitigations and identified that additional risks are often incurred when adopting mitigations for other risks. Overall findings indicate a need for responders to deeply understand their UAS, crew, crew training, and their established CONOP.

2.1.4 Task 4: Analysis of Legislation, Policies, Procedures, and Standards

The research team explored the impact of new legislation on UAS disaster and emergency response and recovery operations. This research explored draft policies, procedures, and standards for UAS supporting disaster and emergency missions. The resulting summarization of these impacts includes insight gleaned from the NDAA specific to UAS technologies and operations in the NAS as well as other UAS, or drone, specific policies that are more directed towards domestic programs, for example, the American Security Drone Act of 2023, and others. This study also highlighted the importance of operational qualifications and training for public safety operators indicating the significance of standardization for multi-agency coordination in data and emergency management. **<u>Please Refer to Appendix C for a complete report of Task 4 research activities and results.</u>**

Sub-Task Research Areas: Task 4 was divided into eight technical research Sub-Tasks addressing questions related to legislation, policies, procedures, and standards regarding UAS operations for disaster response and recovery.

Table 5. Task 4 Technical Research Sub-Tasks.

Sub-Task Title	Research Question(s) Addressed
Impacts of Legislation	What are the impacts of new legislation (such as the National Defense Authorization Act) on local, state, and federal agencies using UAS for disaster and emergency response and recovery missions? What should compliance with this new legislation look like?
Impacts of a Public Safety UAS Pilot Rating	What are the benefits and impacts of a public safety pilot rating beyond the Part 107 remote pilot rating?
Airworthiness Qualifications, Crew Training, and Procedures	What should the additional airworthiness qualifications and crew training procedures look like for disaster and emergency response and recovery UAS operations? Are there any other policies and procedures that need to be developed to expand UAS supporting disaster and emergency response and recovery missions?
Mitigating UAS Incursions During Response Missions	How can UAS incursions during response and recovery missions be mitigated?
Standardizing Practices for UAS Disaster Response	How can disaster and emergency action plans for UAS supporting response and recovery be standardized across local, state, and federal agencies?
UAS Fleets and Policies of Local, State, and Federal Organizations	Investigate the UAS fleet mix of local, state, and federal disaster and emergency response organizations and determine the priority of policies and procedures for the future growth of fleets from organizations.
Determining UAS Typing Standards	Coordinate with the FEMA and the National Wildfire Coordinating Group to determine what UAS typing standards would look like.

Mitigating SGI Process Concerns	How can concerns be mitigated regarding the issuance of Special Government Interests? Look at FEMA's processes regarding an Air Ops liaison.

Task Findings and Results:

Sub-Task 4-1: This research investigated the impacts of legislation that affects entities and organizations that use UAS for disaster response and recovery. The legislation with the most significant effect is the NDAA, particularly a component referred to as the American Drone Security Act of 2023. This legislation restricts government entities from procuring and operating UAS developed, manufactured, and sold from what is referred to as “covered foreign entities”, such as China and Iran. While these prohibitions have an exemption process, this process is not always straightforward or consistent. This hampers an agency’s ability to procure UAS that may meet its mission requirements. The American Drone Security Act of 2023 also calls for a study to identify gaps in the United States’ ability to produce UAS and supporting technologies, such as sensor payloads, domestically. This act intends to identify gaps and shortfalls in the US capacity to acquire domestically produced UAS technologies and determine methods to aid government entities in obtaining UAS compliant with existing laws and regulations.

Sub-Task 4-2: This sub-task addressed the concept of UAS training for public safety entities exploring the application of notional UAS qualification ratings and certifications that offer unique skill sets relevant to disaster response and recovery operations. Findings from this task identify several benefits to specialized training. The most noteworthy finding is that specialized training would increase general competency and safety practices in responders who use UAS for disaster response. Training emphasizing role-specific knowledge and practical skills may better prepare responders to use UAS for disaster response more effectively and safely.

This study also identified opportunities to continue standardization efforts for building UAS pilot skills and competencies. American Society for Testing and Materials (ASTM) F3379 *Standard Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement* represents an existing standard from which training guidance may be developed. It also represents an opportunity for responders to provide input to standards development organizations so that new remote pilot training and operational standards may be created to suit their unique mission requirements.

Finally, this study identified the advantages of remote pilot training and the ability to obtain operations approvals, waivers, and exemptions – e.g., BVLOS, operations over people, etc. Remote pilot training may mitigate risk by leveraging demonstrated knowledge, skills, and abilities against operational risks. Standardized remote pilot training for responders may ensure that operational waivers and authorizations are more accessible and create fewer barriers to safe, effective disaster response operations.

Sub-Task 4-3: Building upon Sub-Task 4.2, Sub-Task 4.3 explores airworthiness qualifications and crew training for disaster response personnel. While Sub-Task 4.2 identified the impacts of

UAS training for public safety and disaster response personnel, Sub-Task 4.3 went into greater detail to determine what those specific skill sets and procedures should be.

The research team explored airworthiness qualifications for public safety and disaster response UAS, identifying two primary approaches – standard and special airworthiness certificates. Neither of these approaches is viable for disaster response operations because a standard airworthiness certificate is only obtainable by the aircraft manufacturer with significant costs in time and capital, and a special airworthiness certificate often comes with very specific operational restrictions. The team also noted that different government organizations have airworthiness criteria, and many can self-declare their systems to be airworthy.

However, the research team notes that small UAS (sUAS) have no airworthiness requirements beyond being in a condition for safe flight. This often makes sUAS more accommodating for public safety operators but does not leave operators without challenges. The biggest challenge for responders who wish to obtain a Certificate of Authorization (COA) or authorization is demonstrating that their system is safe for the operational use case because COAs are often platform, mission set, and operator specific. Without airworthiness documentation for commercial-off-the-shelf (COTS) sUAS detailing the means of compliance with certain safety requirements, COAs or exemption applications may prove challenging but not always restrictive. Many COTS sUAS have standard features for operator and operational safety that are more widely accepted, such as low-battery fail safes and geofencing.

Sub-Task 4-4: While exploring mechanisms to mitigate against UAS incursions into airspace surrounding a disaster zone, the research team arrives at two primary categories to classify UAS incursions: ignorant/careless and nefarious. Addressing UAS operators that fall into one of these two categories provides responders with a better understanding of the scope of the problem and the best tools to address it.

Mitigating the effects of ignorant or careless remote pilots is primarily a matter of responders using the correct information and tools. The regulation outlined in 14 CFR Part 89 – Remote Identification of Unmanned Aircraft requires that all UAS sold in the United States are equipped with a means to broadcast a RID signal. This RID signal may alert responders engaged in disaster response and recovery to the presence of a nearby recreational UAS. This allows them to either take action to identify and address the remote pilot or take measures to remove the threat from the airspace by other means.

Addressing nefarious UAS operations presents a different challenge and represents a counter-UAS problem. While responders have many of the same tools available to them to address nefarious UAS as they do for an ignorant or careless hobbyist flyer, these tools may not be effective against a remote pilot with nefarious intent. In these cases, responders may leverage counter-UAS solutions and agencies assigned to force protection, often a law enforcement agency tasked with protecting authorized entities in a disaster zone, by taking a tiered approach to mitigate the air collision risk and locating the remote pilot responsible for the intruding aircraft.

Sub-Task 4-5: Standardizing practices for UAS operations supporting disaster response and recovery will require large-scale coordination at the national level. This is especially true if the desire for standardization extends from the federal level to state or local departments and municipalities. National level guidance may incorporate findings from previous sub-tasks in this research – e.g., crew training, strategies for mitigating UAS incursions, airworthiness standards, etc. Falling back on existing standards, such as those by ASTM International, National Fire Protection Association, and National Institute for Standards and Technology (NIST), offers a starting point to unify standard practices, procedures, and policies to ensure responders can use UAS effectively to respond to disaster events.

Sub-Task 4-6: The research team used a survey to identify trends in how different emergency services organizations and departments use UAS. This survey identified common types and characteristics of UAS, sensors, and common challenges affecting various kinds of public safety organizations. This survey identified that most public safety entities use electric multirotor UAS and have relatively small fleet sizes. However, there are differences regarding the maturity of operational procedures and maintenance practices. **A more detailed discussion of the survey and the resulting data may be found in Section** Error! Reference source not found. **of the technical research report in Appendix C.**

Sub-Task 4-7: The research team identified resource typing standards in organizations such as FEMA and NWCG for UAS that fall into two primary categories: capability and performance. These resource typing standards allow UAS to be categorized by their primary capabilities and operational functions such that they may be allocated for disaster response. FEMA, for instance, maintains a *capabilities* based approach defining UAS types on functions such as payload type, payload capacity, and flight endurance. The performance based approach for resource typing used by NWCG uses criteria such as aircraft configuration, endurance, data collection altitudes, maximum range for mapping coverage, and sensor payload types. There is some overlap between the *capabilities* and *performance* criteria that are associated with limitations, such as endurance. The main difference between these two organizational approaches is the integration into mission-specific aspects. FEMA identifies capabilities of resources for a wide variety of emergency response personnel while NWCG predominantly focuses on the performance or technical solutions for accomplishing standard mission tasks, such as mapping. Resource typing also explains the minimum training requirements, operational qualifications, and pilot certifications for operators and supporting personnel. UAS resource typing maintains flexibility to changes as regulations and technology development evolves.

Sub-Task 4-8: Addressing and mitigating challenges associated with the SGI process is a significant concern for entities performing disaster response and recovery missions. While the SGI process is designed to enable government entities to gain operational approvals for UAS flight operations, the process may be unpredictable and inconsistent. Anecdotal testimony from responders identified mixed success with the SGI system, with some stating they received operational approvals in real time. In contrast, others stated that their requests took several hours to process. Larger-scale disasters with established Temporary Flight Restrictions (TFR) tended to receive swifter approvals. The variation in response times to SGIs forces responders to plan ahead, establish chains of communication and contacts within the FAA, establish letters of agreement with civil partners, and define criteria for establishing TFRs to save time.

2.1.5 Task 5: Investigation of Data Sharing and Storage Considerations

This research task focused on data sharing and storage considerations for UAS operations in emergency response. An extensive literature review of current strategies and real-world events in which UAS data was shared across institutions and organizations. Focus group meetings with local, state, and federal stakeholders of UAS response efforts were also sources of the current strategies and future initiatives in this area. The findings and results of this task highlight key details about UAS in emergency response. This includes identifying the specific types of UAS data preferred by federal emergency management, criteria that can be used to determine if data collection is necessary for a given disaster, specifications for training professionals involved in UAS data collection, and mitigation efforts to avoid distributing Personally Identifiable Information (PII) from data sets. Additionally, this task highlights the technical and operational requirements for the concept of a central database of collected UAS data and the cybersecurity considerations for UAS. **The accompanying Task 5 Technical Research Report in Appendix D can be used as a framework for the development of a UAS data sharing system.**

Sub-Task Research Areas: Five general sub-task research areas addressed the research questions for A62.

Table 6. Task 5 Technical Research Sub-Tasks.

Requirements and Implementation for Centralized Interagency Data Portal	What would the requirements and implementation look like for a centralized interagency data portal to streamline cross-governmental coordination? What data sharing and storing principles can be incorporated that are currently practiced by federal agencies, such as the Domestic Operations Awareness and Assessment Response Tool (DAART) utilized by FEMA Region 4?
Cybersecurity Risks Associated with UAS Supporting Disaster and Emergency Response Operations	What are the cybersecurity risks associated with UAS supporting disaster and emergency response operations?
Requirements for a Central Database of UAS Capabilities	What are the requirements for a central database of UAS system and sensor capabilities, taking into consideration airworthiness and encryption factors? These capabilities should be based on standard test methods. Platforms should be vetted by real-world practitioners in the disaster and emergency response domain. An agency should be identified to host and maintain this database.
Metrics for the Use of UAS in Disaster and Emergencies	What metrics should be created for the use of UAS during disasters and emergencies? Examples include: Acquisition, maintenance, and operation costs, Percentage of UAS in aircraft fleet, number of UAS operations (by type of disaster), number of vehicle failures per platform during disaster response operations, number of operational failures per

	platform during disaster response operations, effective time of UAS operations (from planning to data delivery), frequency/tempo of UAS operations in an impacted area, and number and density of UAS operations in an impacted area, etc.
Evaluating Drone Data for Potentially Harmful Information	How can we better understand how drone data collected during disasters can be used to cause harm? What would best practices and tools for evaluating data for potential PII and security risks look like?

Task Findings and Results:

Sub-Task 5-1: This sub-task highlights the general requirements and need for a centralized interagency portal for UAS collected data during disasters. Requirements identified include ensuring access for key stakeholders and end-users in the response efforts, an easy-to-use data upload process, search functionality, and review of crucial aerial information. A geospatial data focused database may also help streamline the SGI process for operators in the field and for FAA approvers of SGI waivers. **Section 2.1 of the Task 5 Final Report in Appendix D goes into more detail about the key considerations for this database and workflow processes.**

Sub-Task 5-2: The growing use of UAS in emergency response invites a new set of cybersecurity risks for agencies involved in recovery operations. Data collected during relief efforts are immensely helpful to individuals and communities in need, therefore, it is also incumbent that data providers adhere to best practices for cybersecurity, data protection, and data minimization to ensure their efforts do not inadvertently harm those communities. This sub-task identified commercially available UAS platforms across industry and assessed cybersecurity threats in emergency response use cases. Several best practices documents available from federal government guidelines were reviewed as well for best practices of data management and security.

Sub-Task 5-3: A key finding from this sub-task acknowledged that the UAS industry and market are constantly changing and highlighted the demand for a standardized, well-researched database of UAS and sensor capabilities. Key considerations for this database include identifying the compliance of UAS for federal regulations, comprehensiveness for available aircraft and sensor use cases, credibility from expert evaluators for the effectiveness of aircraft and sensors in disaster response scenarios, the relevance of aircraft and sensor combinations to meet the needs of operators and data managers, and finally the usability of the central database to identify an appropriate aircraft and sensor combination for specific use cases.

Sub-Task 5-4: There is currently very little comprehensive data illustrating how UAS are being used during real-world disaster response and recovery. This sub-task identified knowledge and data gaps that are publicly available to assist agencies and operators in determining application areas for UAS in emergencies. Additionally, documentation from agencies and operators about lessons learned in disaster response efforts go unpublished to help define metrics for success of using this technology. Specific metrics identified by this sub-task include UAS Systems information, organizational information, individual disaster/emergency incident information, UAS operations software, accidents/incidents, data management metrics, and a general UAS response landscape definition. **Each of these metrics is defined in Section 2.4 of Appendix D.**

Sub-Task 5-5: This sub-task investigated several examples of privacy and security risks posed by the increased use of UAS by public safety agencies. Court cases and government guidelines defining some of the issues in the privacy of public information distributed by UAS were reviewed and recommendations for best practices to mitigate these concerns by the proposed "Interagency Data Portal" from Sub-Task 5-1. This proposed process suggests the use of software tools driven by Artificial Intelligence (AI) to automatically flag problematic imagery for review by analysts to ensure no PII is released.

2.1.6 Task 9: Data Collector and Database Development

The final technical task of A62 was to begin the development of a data collector tool and database architecture to capture the requirements of data governance and data management for UAS operations. Data captured by this data collector may be used for flight events, post-event analysis, and other evaluation and analysis efforts. Data collected during the project will be analyzed to produce various key performance measures and metrics that characterize how overall pilot proficiency in a flight environment. Task 9 consisted of four sub-tasks identifying the development requirements, architectural design, data management plan, and data sharing compliance. **More details and graphics describing the methodology and results of Task 9 are available in Appendix E – Appendix H.**

Table 7. Task 9 Technical Research Sub-Tasks.

Data Exchange and Data Collector Requirements	Define and document data exchange requirements with logical models and a data dictionary to support sUAS capabilities and pilot proficiency data. Data must include the necessary performance measures, metrics, and evaluation data provided by medical, police, and fire that will be captured for each flight event and data elements to be exchanged.
Database Design and Architecture	The purpose of this design is to provide a storage and analysis framework for UAS flight test event scenarios and to extract certain data elements from the pilot proficiency and assessment database and store them in a centralized location in the cloud for credentialing purposes.
Data Management Plan	The scope of data management includes the gathering, transformation, and stewardship of drone data collected during UAS flight missions, supplemental data required for building ArcGIS Online Apps, and personally

	identifiable information from UAS Operators and public safety personnel.
Information Sharing and Agreement Compliance	This sub-task is meant to define a fully integrated plan across relevant stakeholders for data sharing and data management related to the Disaster Preparedness and Emergency Response project. Components of the integrated plan include the processes and technologies underpinning the data management system, the data management overview of the integrated plan, the data sharing operating model, and the organization and roles of the sharing entities.

Task Findings and Results:

Sub-Task 9-1: This sub-task outlined the requirements for a conceptual data exchange and collector tool by way of logic models using input of UAS capabilities and pilot proficiency. The resulting workflow architecture should be able to collect data from public safety mission profiles and use cases to include but not limited to live video feeds, geospatial mapping products, flight event data, and pilot proficiency information. In addition to collecting this data, an effective tool will also aggregate this information into a logical means to review, monitor, and analyze this data in an easy to navigate user interface. Storing this data in standardized formats used by geospatial and public safety professionals is integral to the adoption of such a tool, for instance, the file formats of video, models, video, and flight data. Analysis, report sharing, and web-based interfaces are important to the adaptability and interoperability across users.

Sub-Task 9-2: In describing the database architecture for use in disaster preparedness and emergency response programs, this sub-task developed a general framework for extracting information from flight test scenarios. The data from test scenarios allowed the research team to create logical data models with associated subsystem components for potential integration into other tools or data formatting. Azure Structured Query Language was used for ingesting collected data and associating inputs to relevant components. Azure App Service for hosting webservers and Azure Cloud Storage for hosting files were also tested for this framework. Example models include aggregating UAS flight data that may be uploaded to a flight events monitoring tool, such as a ground control station, pilot proficiency information that may be added to a pilot record profile, and GIS desktop and web-map services for geospatial data products. **Graphics of these models can be found in Appendix F.**

Sub-Task 9-3: A data management plan was developed for flight event data by individual operators to include a flight profile consisting of maneuvers, payload functions, other sensors on the aircraft, such as altimeter and global positioning system, flight endurance, and radio communications. Other metrics aggregated from this information and used in the data management plan include safety assessments, aircraft durability, and operational logistics. This data management plan was defined as a Flight Events System which serves as a centralized management hub where flight data can be collected and disseminated in support of operational management. The concept is meant to establish an automated data pipeline through which data gathered during a UAS flight are ingested, organized, and relayed directly to analysts and decision makers.

Sub-Task 9-4: This sub-task helped define the components of an integrated plan for ingesting and disseminating information about the technology used, data workflow processes, storage requirements, and organization permission. Two specific models were detailed as a result of this sub-task. The Operating Model was the framework for managing the implementation of the tools created in Task 9 across multiple platforms, metrics for aggregating relevant data, and data governance. The Organization and Roles Model was structured in a way to manage team governance, stewardship of team permissions, and infrastructure requirements. The underpinning data management system is meant to provide an overall integration plan for potential end-users with both a data management plan and a process to share across multiple entities.

3 ADDITIONAL USE CASES IN PHASE III

3.1 Task 6: Conduct Domestic and International Outreach

Research efforts under the A62 program included a requirement to conduct regular outreach efforts both domestically and internationally. These outreach activities sought to expand the scope of the network community of emergency response practitioners and engage that community in the research efforts of the program. Various types of permitted activities included conference attendance, workshops, engagement with working groups, and flight testing events. The research teams across all of the participating institutions provided regular updates during the monthly TIM and Program Management Reviews (PMR) to both the ASSURE project leadership and the FAA sponsor. Table 8 outlines these events during the POP captured during the TIM and PMR meeting minutes at the time of writing the A62 Final Report.

Table 8. Outreach Activities of A62 Research Team.

Date	Performer	Description
12/21/2022	UAH	Briefed the NASA Earth Science -Disasters Team at the National Space Science and Technology Center on the A62 Program and received interest in supporting efforts
12/22/2022	UAH	Conducted UAS night flight demonstration with UAH Police Department and discussed pathways for disaster preparedness on campus
2/15/2023	UVM	Fire Department of New York Engagement Meeting
2/15/2023	UVM	NIST Flight Demonstrations and Pilot Proficiency Training
2/15/2023	UAH	Multi-Agency Training Event with Civil Air Patrol UAS Teams and SARTEC K-9 Teams
4/18/2023	UAH	Practiced Air Boss functions with DOD customer during a swarm demonstration at the Huntsville International Airport

4/23/2023	NMSU	Attended the Wildfire Technology Management Summit in Pasadena, CA to engage with DOI, FEMA, U.S. Forest Service, CAL Fire, NASA, and the Canadian Interagency Forest Fire Centre
5/10/2023	UAH	Attended the NASA "Tropospheric Emissions: Monitoring Pollution" Science Meeting to engage with NASA and NOAA on UAS air quality monitoring applications
6/21/2023	UAH	Hosted Meeting with the "Atmospheric Emissions and Reactions Observed from Megacities to Marine Areas Operations Team to potentially support UAS operations in future field campaigns and incorporate disaster resiliency research
7/19/2023	UVM	Supporting Flood Response Efforts from July 2023 Flooding event
8/16/2023	UAH	Personnel completed FEMA Courses for Incident Command (NIMS 300 and 400) to receive certification and engage with the FEMA Center for Disaster Preparedness
8/16/2023	UAH	Met with the Department of Transportation Innovation Office to discuss swarm operations application areas for disaster response and recovery of transportation ways
11/5/2023	NMSU	Attended the Border Technology Summit in San Antonio, TX to meet with DHS Counter UAS Program Management Office, DHS CBT, Coast Guard, and Texas TPS
11/15/2023	UAH	Supported the UAH College of Nursing Campus Disaster Drill in Huntsville, AL. Provided UAS operations, medical delivery flight tests, and multi-agency coordination CONOP
12/20/2023	KSU	Began meeting with coordinators of the Country Stampede (June 2024) to plan for UAS flight operations and integration into multi-agency efforts
1/17/2024	KSU	Began regular meetings with Emergency Manager for Country Stampede to coordinate UAS efforts during the event in June
2/21/2024	KSU	Hosted initial meetings with MITRE, Kansas Department of Transportation, and KSU to develop future capabilities for COP
2/21/2024	NMSU	Attended the FEMA Region IV Higher Education Collaborative Summit in Houston, TX to present on Research and Training for first responders and promote research addressing homeland security and emergency management issues
2/27/2024	UVM	Attended the 2024 Disaster PRIMR to present during the Interfaces of Disaster Panel on the 2023 Vermont Flood Response

3/12/2024	NCSU	Attended the 2024 National Public Safety UAS Conference in Williamsburg, VA
3/19/2024	UVM	Presented at the Resilient Vermont Conference on Flood Response Efforts
3/28/2024	UVM	Presented at the Vermont Association for Wetland Science on Flood Response and to engage with wetland professionals
4/5/2024	NCSU	Attended the North Carolina Statewide Search and Rescue Exercise (HOKE SAREX) in Raeford, NC
4/17/2024	UVM	Attended the Yellowscan LiDAR Conference 2024 to present on Vermont Flood Response Efforts and perform international outreach
4/24/2024	UVM	Presented at the AUVSI Main Stage during the Environmental Systems Research Institute, Inc. (ESRI) Conference on flood response efforts and outreach with first responders
6/11/2024	UVM	Participated in the Advanced Technology in Public Safety Workshop hosted by NAPSG and MIT Lincoln Labs
6/24/2024	UAH	Participated in the 2024 Catastrophic UAS and Remote Sensing Exercise (CURSE) tabletop exercise with one strike team and geospatial analyst
6/27/2024	UVM	Established the Vermont UAS Response Working Group
7/15/2024	UVM	Attended the ESRI User Conference in San Diego, CA
8/13/2024	UVM	Attended the Global Autonomous Systems Conference in Anchorage, AK to present on the Innovation for Operational Use Emergency Response Panel
8/26/2024	UAH	Participated in the NATO SAPIENCE Competition in London, UK hosted by City College and sponsored by the NATO Science for Peace and Security Programme. Conducted international outreach with partner institutions and public safety professionals
9/11/2024	UVM	Presented at the Vermont Emergency Preparedness Conference in Fairlee, VT
9/19/2024	UVM	Attended the Wyoming Computing Symposium to present at the Disaster Response and Environmental Impact panel
9/23/2024	UAH	Hosted a Minimum Operational Proficiency Standards Public Safety Training Course in Huntsville, AL, with ASSURE Partner Institutions
9/26/2024	UVM	Attended NYC Climate Week to participate in the "Sky's the Limit: Drones in Climate Adaptation" Panel

10/29/2024	UVM	Presented at the Northeast Arc User Group Conference in Burlington, VT
10/29/2024	UVM	Supported Vermont Fire Department Safety in Wildland Fire response efforts in Barnard, VT
11/7/2024	UVM	Hosted a seminar on UAS/GIS Workflows for Flood Response at the Connecticut Emergency Management GIS Working Group meeting
12/9/2024	UVM	Hosted the Vermont State UAS Working Group Quarterly Meeting

3.2 Task 7: UAS Flight Testing Events and Scenarios

This project included provisions for partner institutions to perform mock and real-world operations to support the full range of disasters and emergency services. The objective of Task 7 was to conduct outreach with local, state, federal, and international communities involved in disaster response and recovery to embed university capabilities in relief efforts and expand the scope of ASSURE research outcomes. These events and activities should inform technological solutions to enable expanded operations of UAS, assess the optimal UAS capabilities for various disaster types, define the proper coordination procedures amongst multi-agency collaboration, and capture valuable metrics of UAS to enhance the standardization of operational best practices as well as best practices for data collection and sharing. Flexibility was allotted to participating universities to also identify additional findings from engagement during these events. **The full reports detailing the full extent of the activities performed and the lessons learned by the ASSURE teams are available in Appendix I – Appendix K.**

Research Questions Addressed During Task 7 Activities:

1. How effective are the policies, procedures, and guidelines used in the exercises?
2. When a disaster or emergency happens, what should future coordination with federal governmental agencies look like when UAS are fully integrated into the NAS?
3. What UAS-related technological advances will benefit the use of UAS in a disaster or emergency response?
4. What are the barriers to entry for local, state, and federal organizations employing UAS technology for disaster and emergency response and recovery?
5. What enabling technologies or advancements would aid future disaster preparedness and emergency response?
6. What data should be gathered to support lessons learned and process improvements?

3.2.1 University of Vermont

UVM participated in three major events during the POP of A62 for two specific types of disasters: large scale oil spill response exercises in partnership with state agencies and extensive damage assessment operations supporting flood response efforts from the impact of Hurricane Beryl. **Please refer to Appendix I for more details about UVM Task 7 activities.**

3.2.1.1 Oil Spill Functional Exercise

The functional exercise that UVM participated in as part of ASSURE took place at Lewis Creek in North Ferrisburgh, Vermont, on June 12, 2024. The scenario aimed to simulate an event where an oil spill from rail traffic or a tanker truck occurred along a major roadway. The exercise required collaboration between representatives from numerous agencies including ground teams for oil boom deployment and aerial teams for UAS deployment.

UAS provide numerous valuable capabilities in responding to oil spills, as demonstrated in this functional exercise. Collaboration between regional agencies and the UVM UAS Team allowed for robust testing of UAS operations during the mock oil spill and helped identify knowledge gaps in policies, procedures, guidelines, best practices, and coordination. The key objectives sought to identify the multi-agency coordination efforts and communication procedures for integrating UAS into an oil spill and transportation response, establish real-time data availability for first responder situational awareness, and process geospatial data products from UAS.

Oil Spill Lessons Learned (from Task Report): An initial challenge during the exercise was the limited space in the response staging area, which highlighted the need for thorough pre-deployment planning and analysis of site considerations when possible. Before deployment and on site, UAS operators would have benefited from increased communication and coordination with personnel involved in the Geographic Response Survey (GRS) operations. In this exercise, the lack of communication caused a disconnect between the GRS oil boom deployment and how the UAS team could best support their efforts. During emergency events, this disconnect could be avoided by establishing a clear understanding of each other's operations and encouraging direct communication throughout the response.

Airspace partitioning and communication between UAS teams were crucial to successful airspace deconfliction and mitigating risks of simultaneous UAS operations. Radio and verbal communication between pilots and visual observers were successful, but is further research needed to establish when a designated air boss may be necessary. The selected UAS proved instrumental in carrying out the mission type and objectives, but there are associated knowledge gaps that remain, especially around standardizing methods and best practices, as well as sensor integration. Continued connection, collaboration, and training are needed amongst agencies to improve best practices and continue to develop the appropriate protocols for UAS response to an oil or hazardous material spill.

3.2.1.2 7/11/2024 – 7/13/2024 Hurricane Beryl Flood Response in Washington County, Vermont

Hurricane Beryl's remnants hit Vermont on the night of July 10 and into July 11, 2024. The storm caused rapid water-level rises in rivers such as the Winooski, Passumpsic, and Lamoille, with some areas experiencing over seven inches of rain. The most severe impacts occurred across the center of the state, with cities and towns in Washington County being critically impacted as they continued to recover and rebuild from the Great Vermont Floods of July 2023. By the morning of July 11, Type III Urban Search and Rescue and Swiftwater Rescue teams had carried out more than 118 active rescues, 12 evacuations, and 16 pet evacuations. The Vermont Agency of Transportation determined that more than 100 bridges across the state were damaged, and 185 miles of Vermont state roads were closed due to the flooding.

UVM's contributions to flood response following the impacts of Beryl expanded far beyond the efforts in these two locations. In total, UVM completed 143 sUAS flights between July 11 and July 22 in response to requests for support across the state. The tasking and execution of these missions included the capture of oblique aerial imagery, aerial video, and mapping data such as 2D true-color orthoimagery and 3D UAS-Light Detection and Ranging (LiDAR) elevation products. These flights resulted in the generation of over 1 terabyte of raw and processed data products during this period.

Lessons Learned During Flood Response Event (from Task Report):

- SGI request process
  - The FAA's SGI procedure can be less responsive and rapid than expected, particularly during times in which a series of disasters are impacting areas across the country and when the System Operations Support Center (SOSC) is unable to have multiple staff available to process requests.
  - How requests are prioritized for SGI approved by the SOSC is opaque to the requesting organization, particularly for flood response efforts when capturing high-water marks in UAS imagery can make a significant impact towards expediting the distribution of recovery funding.
  - Best practices and standardized training for submitting SGI requests would benefit both the requesting organizations and the SOSC to improve efficiency.
    - What organizations count as public safety?
    - What materials do organizations supporting public safety agencies need to provide to be processed under the SGI process?
  - Developing flight areas using a polygon allows for more specific requests for waiver/authorization via SGI. UVM used Google Earth to draw a polygon covering the requested flight area and document coordinates of the vertices, which was cumbersome to convert from a geospatial file to a list of text coordinates.
- Communication and tasking
  - Communication and collaboration between local/regional organizations that are familiar with the capabilities and capacities of different UAS teams is extremely valuable.
    - The Vermont Agency of Transportation UAS Program Manager knew that UVM UAS had OOP capabilities and sufficient crew members to carry out mapping over cities and towns, such as Barre and Plainfield.
  - The UVM team was contacted directly by local agencies and first responders who were familiar with their capabilities, but there was confusion about who they should be directed to for official Emergency Operations Center (EOC) taskings.
  - Having community members or personnel that are familiar with locations of interest support UAS strike teams to navigate and communicate.
    - During the response in Plainfield, the UVM Team communicated with Plainfield Emergency Management contacts before the response to ask for recommendations for good staging areas for flights. With recommendations for staging areas and liaisons, navigating Plainfield became much more efficient, especially with road closures throughout the area.
    - In Barre, since areas of interest were the same as in previous responses, the UVM Team was already familiar with and knew of successful staging areas which made traveling through Barre more efficient.
- Data management and processing
  - UVM utilized a spreadsheet to keep track of every flight and dataset collected during the response, allowing for detailed tracking of data collection, processing, and sharing status.

- A cloud-based photogrammetry solution for orthomosaic and integrated 3D mesh generation more efficient and scalable compared to using software running on local workstations. Solving challenges related to sharing these data products directly to ArcGIS Online (AGOL) allowed for streamlined sharing and integration of layers to public-facing portals.
    - Local base stations, such as Continuously Operating Reference Station (CORS) stations, during this response were running as normal in contrast to the previous response, where several CORS stations were downed due to flooding damage. These local base stations allowed for the accurate positioning of data and images which also speeds up the process of orthomosaic regeneration. With the VT CORS system up, Real-Time Kinematics (RTK) was readily available for imagery and meant no need for Post-Processing Kinematics (PPK) images during processing.
- Data dissemination and application
    - In contrast to the previous flood response data dissemination strategy of having the Vermont Center for Geographic Information (VCGI) create its own AGOL group to digest data through, UVM instead created its own and shared access to VCGI. This allowed for an easier time for sharing datasets directly to the group, instead of having to upload and send datasets via file transfers to VCGI which was done during the previous response. With the UVM AGOL group, UVM was able to process data through ESRI Site Scan cloud processing for orthomosaics and 3D meshes and instantly upload them to the cloud. VCGI then was able to grab those datasets from the cloud much quicker, without having to download them and integrate them into web apps for public access and FEMA SARCOP integration.
    - UAS-LiDAR
        - Topological data provided base plans and cross sections and identified critical features for future engineering designs.
        - Cross sections were used for slope stability modeling to identify areas of instability and to develop mitigation strategies for infrastructure.
        - LiDAR models from July 2024 were compared to past data captures (UAS-LiDAR and aerial LiDAR) to understand changes in the slopes.
        - UAS-LiDAR removed the need to send personnel to survey the landslide by hand. This allowed data capture of inaccessible and dangerous locations by foot and provided high resolution and high accuracy data of the slope.

UAS-LiDAR allowed for rapid data capture which may have taken days or weeks without the use of UAS. This allowed for quick decision making for temporary measures to allow residents to evacuate or find other means of navigating around the landslide. Data later was then used to make longer-term solutions before the winter season.

3.2.1.3 7/30/2024 Flood and Landslide Response Event, Northeast Kingdom, Vermont

The State of Vermont was impacted by flooding, landslides, road washouts, and catastrophic damage following severe storms from July 29-31, 2024. The initial rainstorm beginning in the late hours of July 29th dropped between six and nine inches of rain causing flash flooding across the state, with the worst of the storm focused in Vermont's Northeast Kingdom (NEK). During the state's third devastating flooding incident in just over a year, countless road closures were put in place, swift-water rescue teams were activated to reach stranded residents, and a State of Emergency was activated in Vermont. UVM's UAS Team began sUAS flight operations to support response and recovery efforts on July 30, 2024, and operations continued through August 7, 2024. In total, around 40 individual sUAS flights were carried out in support of the flooding event. On September 26, 2024, the July 29-31 event officially received a Major Disaster Declaration from President Biden.

This functional exercise presents a set of sUAS flight operations in the towns of St. Johnsbury and Lyndon, to document water levels, road washouts, landslides, infrastructure damage, and other impacts from the flooding event. These operations took place in some of the most severely impacted regions in the state (**Error! Reference source not found.**) and were particularly illustrative of the variety of challenges and lessons learned during the overall flood response.

The purpose of these operations was to acquire UAS imagery and mapping data to visualize the flooding extent and damage in hard-hit regions, support rapid geospatial damage assessments and additional analysis, provide documentation to support a request for a federal disaster declaration and aid in future flood resiliency research and planning. This real-world response also served as a way to evaluate the UVM UAS Team's procedures, capabilities, limitations, processing, and dissemination activities while capturing lessons learned and best practices for future operations.

Lessons Learned from the Flood and Landslide Response Event

- Requests by individual agencies were able to guide UAS response and produce valuable data, but teams would benefit from more organized tasking and response operations under the EOC and ICS for future response efforts. This would streamline requests, improve efficiency, and potentially minimize funding limitations.
- Without direct tasking, a combination of resources can be useful in prioritizing areas to respond to including local rainfall estimates and flood gauges, news reports of damage, and insight from response agencies.
- Following a disaster event, road closures, and washouts can make it challenging to access sites for UAS collection.
- During an emergency response, multiple UAS teams may be responding to the same area, resulting in a need to communicate and deconflict airspace.
- Maintaining Visual Line Of Sight (VLOS) and C2 to the UAS can be difficult depending on the access and terrain of the response area, potentially limiting operations until more suitable access sites become available or the availability of BVLOS provisions.
- Emergency response and natural disasters are unpredictable and therefore UAS pilots and teams must have flexibility in terms of equipment, operation areas, flight planning, automated vs manual flight, and other aspects of operations.
- A combination of manual flight and automatic triggering of images can collect useful data when automated flight plans are not feasible. If done correctly, even a singular pass along a corridor can produce suitable mapping results without significant requirements for automated flight planning.
- Mapping imagery collection towards dusk can result in poor interpretability of features in the orthomosaic, but could potentially be rectified through editing.
- RTK or PPK collection will improve UAS data accuracy, but RTK imagery collection is especially helpful for speeding up processing times by eliminating the need for geotagging the photos

- Processing mapping imagery in a cloud-based environment allowed multiple members of the UAS Team to begin processing online while they continued other operations, improving the ease and speed of orthomosaic generation. There are still limitations to processing in the field, however, due to slow speeds over wifi networks.
- LiDAR collection may be more limited than imagery collection due to the typical lower altitude during flights which can inhibit VLOS and C2.
- LiDAR processing takes significantly longer to process than imagery, requires specific software, and involves more complex workflows that could present challenges and setbacks.
- UAS photogrammetric point cloud generation can provide suitable computer aided design integration for geotechnical engineering solutions/
- A public web application containing multiple types of data from the three flooding events, comparison views between pre- and post-flood imagery, and 3D capabilities were a valuable resource for stakeholders to view affected areas, identify debris, document damage, and more.
- The data sharing workflow from UVM's SiteScan projects, directly to AGOL, and into a designated group with VCGI allowed for rapid integration into public applications made available to FEMA, state agencies, and members of the public.
- Internal practices including pre-flight checklists, pre-mission checklists, data tracking spreadsheets, workflows, and standard operating procedures were essential in carrying out safe, efficient operations and organized data processing and delivery.

3.2.2 Kansas State University

KSU supported a live event with multi-agency coordination and integrated UAS to extend situational awareness for the Kansas State Fair from 9/6/2024-9/15/2024. Over the ten-day period, the Kansas State Fair accommodated 350,000 people which required a large scale public safety presence including law enforcement, fire departments, and emergency medical services. There were two key objectives from this event which included implementing UAS to deliver real-time data directly to incident commanders for improved communication and to evaluate a precomposed COP developed by the State of Kansas to integrate UAS into large-scale events.

The COP was developed in partnership with KSU, the Kansas Department of Transportation, and The MITRE Corporation which used the Team Awareness Kit (TAK), an Android application software to integrate ground and air assets. Live UAS video and static camera video feeds were integrated into the TAK COP. The KSU team conducted over 24 flights with over 12 hours of flight time during the event. **A detailed overview of the KSU Task 7 activity and UAS flight test plan is available in Appendix J.**

3.2.3 New Mexico State University

A Mock Airplane Crash Emergency Response test was conducted by the New Mexico State University ASSURE team in early November 12th and 13th, 2024. The main objectives of this functional exercise were to test UAS flight systems, sensors, equipment, and procedures in the context of a crashed airplane scenario, collect lessons learned, and assess the post-processing of the data products necessary. The location was coordinated with College Ranch Management. The UAS flights were conducted by NMSU, with additional support from personnel associated with police, fire, and search and rescue experience. The initial flights included many Electro Optical

(EO) and thermal search flights with a simulated survivor and hazard. The secondary flights were completed with multi-spec, EO, and LiDAR for mapping the crash before and after the wreckage was removed. **More details about the NMSU Task 7 activities are available in Appendix K.**

Lessons Learned Summary from Airplane Crash Exercise (from task report):

All the fight missions were completed safely under Part 107 operations. There were no safety challenges or issues. There were a few minor equipment challenges that were encountered. All the items were captured in these 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. NMSU teams captured these lessons learned or reinforced some of 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 Airplane Crash Response. These key notes are broken down by aircraft or required support function.

- Mapping products consume time post-flight to produce rendering the EO, thermal, and LiDAR images and 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 resolution and unfortunately, did not prove useful in identifying even the larger crash panels such as the wings or fuselage. The most useful of the Trinity maps is the EO mapping allowing the user to see a full picture of the mock crash area and zoom to parts for further identification.
- One of the UAS (Teledyne) had an issue with maintaining the desired heading which was attributed to not performing a calibration. It had been flown at the airport numerous times without issue, and the other UAS did not have a problem. It was determined this particular system requires a compass calibration every time it flies in a different location regardless of how close the last position was.
- Display of the UAS location in a coordinate format is not standardized or, in some cases, not available on the viewing screen without the UAS returning to the takeoff point (Teledyne). The Skydio 2 and Skydio X2E could not display the coordinates in the camera view, only if you switched to the map view. The DJI Matrice was able to display coordinates if you used the laser range finder, otherwise it was not available. This coordinate directly indicated where the range finder was impacting the ground, not the position of the aircraft. It is very important to be able to pass on coordinates of survivors and any wreckage, to the first responders.
- The Trinity had a battery issue shortly after takeoff. The system recognized a problem and returned to land without incident. After replacing the battery, no further issues were noted with the system.
- There was an issue with the Sony camera shutter which is utilized by the Yellowscan LiDAR on the X6. The team was able to complete mapping using the Yellowscan LiDAR; however, the camera did not provide the geotagging necessary for development. The team was able to perform a work-around in post-production using the location information from the Trinity.

- Operations obscured by mountainous terrain can lead to varied and shifting wind speeds and direction. It did not prevent operations, and the crew was able to adjust the takeoff direction through the Trinity operator software interface. Winds did affect the operation of the small UAS on the first day. The weather station was indicating between 8 and up to 12MPH on the ground but the UAS was indicating as high as 28 mph at 200 ft which limited the operations of the Teledyne (22 mph maximum for position hold). It also impacts battery life as the wind increases the load on the UAS, reducing the total flight time.
- Cooler temperatures early on did cause a slight delay in takeoff on the X6 using a Cube autopilot. There is an optimum temperature that the Inertial Measurement Unit (IMU) needs to be at so it will "warm" itself and delay takeoff until the optimum temperature is reached.
- The rugged terrain and lack of roads (essentially a trail) provided a realistic environment for the team to operate out of. The team was required to transfer equipment and personnel into 4-wheel drive vehicles at College Station Ranch before continuing on the trail to the proposed flight operations location (base camp). From there, UAS were used to locate the survivor/wreckage and to guide the "Rescuer." Specific communications (using clock positions or saying left turn, stop, turn, continue forward) were briefed before the rescuer headed out. This points toward specific operational protocols to enhance safety.
- The Matrice EO images were the most effective and would have been very useful during an actual search and rescue. Altitudes remained within Part 107 limitations; however, that did not hinder the ability of the pilot to locate the survivor quickly because of the excellent resolution of the camera and the larger size monitor of the controller.
- There was a question of how well the LiDAR would work for mapping the accident site for post-accident investigation and this was explored. Unfortunately, the LiDAR, in the team's opinion, was not able to provide a high-quality detailed picture of the accident wreckage and would not prove useful for providing high-quality images for post-accident investigation purposes.
- The thermal camera on the Teledyne was very effective and made it much easier to identify a live person (survivor) at an accident site. You can quickly identify potential survivors. This would prove less useful for identifying bodies in a recovery mode after they have cooled to ambient temperatures.

The Mock Airplane Crash Emergency Response Test was executed as planned and detailed in the FAA approved Test Plan and Test Cards with UAS flights over the two testing days (Appendix K). The observations and conclusions for this event are presented below. The flights included several mapping flights, a free-flight multi-copter with a LiDAR sensor, and multiple small multi-copters to capture images, thermal images, and video.

The 19 different flights covered all the desired muscle movements and system checks. The few lessons learned that impact potential future missions included the following:

- Local flight area obscurations can cause adverse weather conditions and impact flight operations.
- Being able to identify the location of a survivor or even just the wreckage is a necessary tool to assist first responders. There is a need for UAS manufacturers to make it easy for a UAS Pilot to identify the location (latitude and longitude) of the UAS so they can pass the

information on to the first responders. In this test, one system would display the UAS location but only when in the map mode, not the camera mode. Another model would give the information, but you had to fly back and download it from the storage device card. The one system that could display the “target” location in camera mode was the Matrice which uses a laser range finder.

- Thermal can be more useful than a straight EO camera in particular if there are shadows or cover. Survivors will normally seek cover from the elements (as demonstrated in this test) which will make it more difficult to find them. With thermal, even if just a small portion of their clothed body is exposed, they can display a significant color difference from the surrounding vegetation, dirt, or rocks.
- This scenario had a simulated first responder that the drone was able to guide either by flying over the survivor or using a radio to communicate what direction to walk. If the researchers had simulated a situation where first responders were not readily available or the terrain was such that they could not immediately reach a survivor, the team quickly realized there was no useful way to contact to survivor to relay intentions. Having some type of speaker, possibly dropping a phone or similar communication device, or even having supplemental lighting could assist in this. This is an area worth researching further.
- Cooler temperatures can require longer IMU warmup times delaying takeoff until they are at the required temperature.
- There can be unplanned wind limitations caused by the effects of a crash being located in hilly or mountainous terrain. Funnel effects or turbulence created by winds coming over the top of the hill can affect smaller systems' ability to maintain position or provide a good picture.
- The thermal images on the Teledyne were very effective in being able to see the mock survivor, in particular when looking into the shadow of the hill in the early morning lighting. It was much easier to identify the survivor against the cold ground rocks and to see them despite the vegetation (large Yucca or bushes). Picture quality was adequate to identify the survivor and the large aircraft panels but the zoom wasn’t unlimited, so there were specific zoom settings that had to be selected.
- Altitudes varied depending on the payloads. The UAS doing a visual search was one hundred to approximately two hundred feet Above Ground Level (AGL). The Trinity was flown at three hundred and eighty-three feet AGL for mapping and the X6 with LiDAR was flown at two hundred and sixty-two feet AGL.
- The DJI Matrice had the best zoom and picture quality. The Skydio 2 was not quite as detailed a picture as the Matrice however it was more than adequate for the purpose of identifying and assisting in mapping the wreckage site.
- The DJI Matrice has superior zoom and would also take a stand-off picture as well as a close-up when the photo trigger was pressed. This was useful in determining where the object was that you were zooming in on.

The LiDAR and Multispectral cameras were not useful for post-accident investigation or in determining if the crash site was cleared of all debris. It was unable to sufficiently paint the crash objects well enough to differentiate them from the rocks, boulders, or plants. An increased scale of objects may deliver more visible results, but will still lose fidelity on smaller items.

3.3 Task 8: Development of Required Documentation

This task outlines the requirement to properly document the research efforts, outreach activities, and practical exercises or flight testing events during the period of performance of A62. Each task was assigned a lead performer, or performers, and supporting performers where the responsibility to document activities was the responsibility of each performer but the lead performer aggregated inputs for reporting to ASSURE and the FAA sponsor. This documentation, for example, the Task Final Reports found in the appendices of this final report, were reviewed internally by ASSURE and subsequently reviewed and accepted by the FAA sponsor. Once accepted, these reports were posted to the FAA file share system and shared across the COE. The responsibility to aggregate all reports was assigned to the lead partner institution of the A62 program to compose this final report as the program ends.

4 CONCLUSION

During the period of performance that the A62 program ran from 2022-2025, the United States sustained 73 disaster events that exceeded one billion dollars in damage and lost 1,543 lives, according to the National Centers for Environmental Information (NCEI, 2025). This unfortunately does not include the devastating wildfires in Los Angeles that began in January 2025 which have resulted in devastating impacts to life and property. As has been found in all previous phases of the ASSURE COE research on applications of UAS disaster preparedness and emergency response, the most valuable outcomes from the multi-year projects continue to be the connections made between the research institutions and the public safety community seeking new ways to support communities affected by disaster. The research conducted by the ASSURE COE universities, industry collaborators, and government partners are directly influenced and guided by the challenges communities and public safety professionals during emergencies which in turn help define the policies, procedures, standards, and operational best practices to effectively use UAS as a value adding tool. During A62, the emphasis on exploring technological solutions of both UAS and supporting technology, such as GIS, autonomous operations, and UAS traffic management, in turn also helps define areas where research and development can play a key role in improving disaster response and recovery. The importance of preparedness by way of training, developing proficiency, and exercising with known and new entities and technologies provides the foundation for a more disaster ready nation.

Detailed reports of the technical research tasks (Tasks 2-5 and Task 9) exploring technological solutions to enable expanded operations of UAS in the disaster response landscape remain useful as references to learn about and understand potentially useful technologies but remain inherently incomplete. This is because the transition from research to operations is a constantly changing environment and rightly so to determine what tools are best suited for a given scenario, end user, and timeline. The integration of these technologies and tools in tabletop and functional exercises play a crucial role in this research to operations transition. The continuation of these programs into A84-Phase IV fosters this approach by identifying more technology solutions to explore, such as the growing field of "Drone First Responders", increased autonomy for decision making and managing airborne operations, counter-UAS, and best practices cybersecurity protection are the follow-on technical research topics identified by the results and findings from previous phases. Substantial support in the fourth phase is allotted for the ASSURE COE research team to conduct flight events and exercises with public safety partners made during previous phases and identify more trusted entities to join the community of practice implementing UAS in disaster response.

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6 APPENDICES ATTACHED IN PDF DOCUMENT