The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

UNIVERSITY OF ALASKA FAIRBANKS

MISSISSIPPI STATE

NM STATE

NC STATE UNIVERSITY

Oregon State University

The UNIVERSITY of VERMONT

Final Report
ASSURE A28: Disaster Preparedness and Response Using UAS
Attachment 7 – Concept of Operations (CONOPS) for Train Derailment

June 1, 2022

TABLE OF CONTENTS

TABLE OF ACRONYMS

ACUASI	Alaska for Unmanned Aircraft Systems Integration
BVLOS	Beyond Visual Line of Sight
CONOP	Concept of Operation
DAA	Detect and Avoid
DLI	Divert Land Immediately
DOT	Department of Transportation
EO	Electro-optical
EVLOS	Extended Visual Line of Sight
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FMV	Full Motion Video
FOV	Field of View
GCS	Ground Control Station
GEOJSON	Geographic JavaScript Object Notation
IFR	Instrument Flight Rules
JPEG	Photographic Experts Group
KML	Keyhole Markup Language
KMZ	Keyhole Markup Zipped
LAANC	Low Altitude Authorization and Notification Capability
NAS	National Airspace System
NOTAMS	Notices to Airmen
ORA	Operational Risk Assessment
PIC	Pilot in Command
RGB	Red, Green, Blue
RTB	Return to Base
SAR	Search and Rescue
SGI	Significant Governmental Interest
SHP	Shape file
SOSC	System Operations Support Center
TFR	Temporary Flight Restriction
TIFF	Tag Image File Format

UAS	Uncrewed/Unmanned Aircraft System
USGS	United States Geological Survey
VFR	Visual Flight Rules
VLOS	Visual Line of Sight
VNIR	Visible and near-infrared
VO	Visual Observer
VTOL	Vertical Take-Off and Landing

ATTACHMENT 7 - CONCEPT OF OPERATIONS (CONOPS) FOR TRAIN DERAILMENT

Lead organization will demonstrate that the CONOP has been reviewed. The CONOP will be accepted if the document contains sufficient information to proceed to an operational risk assessment (ORA). <u>The CONOP is to be submitted by the lead organization for the mission.</u>

Approval by (Name/Org)	Title	Date	Approve Digital Signature

This CONOP will include all items needed to build out a successful mission. There will be sections included that are specific to each disaster response in the CONOP, such as under purpose of mission. Any specific information needed in the CONOP for a disaster response will be included before the summary section.

This CONOP document follows the "5-paragraph order" format, leveraged from the military operations world. The purpose is to allow operational team members to determine whether an applicant explicitly identifies key information that will be necessary for a subsequent **Operational Risk Assessment (ORA)**. These paragraphs spell out the acronym **S-M-E-A-C, for "Situation", “Mission”, “Execution”, “Administration & Logistics”, “Command & Signal”**. This is known as the “SMEAC Sheet”.

List of Revisions			
Revision Description	Approved by	Approve Digital Signature	Release Date (DD/MM/YY)

<u>Notes on a CONOP:</u>

The CONOP is viewed as an "evolving" document that records an analysis performed during the requirements generation process and should contain the following:

- A clear statement of the goals and objectives
- Strategies, tactics, policies, and constraints that describe how security will affect the program
- Organizations, activities, and interactions that describe who will participate and what these stakeholders do in that process
- A clear statement of the responsibilities and authority of the roles played in the process
- The specific operational processes, in overview fashion, that provide a process model in terms of when and in what order these operation processes take place, including such things as dependencies and concurrencies
- Processes for initiating the program, developing the products and components, maintaining the products, and components, and possibly for retiring the program and its products and components

CONOP:

- Narrate the processes to be followed
- Define the roles of the various stakeholders involved in the process
- Outline a methodology to realize the goals and objectives of the mission

1.1 Concept of Operation (CONOP)

Train Derailment in Vermont that impacts local infrastructure and needs assessment of any fuel leaks on local environment

Operation;

Train Derailment at Essex-Junction Amtrak junction and station near to Burlington, Vermont and impacted local infrastructure

Duration of Operation;

A Few hours (Report of train derailed; Search and Rescue (SAR) needs to be quick, Bridge assessed for safety)

Outcomes/Actionable intelligence:

- Large Unmanned/Uncrewed Aircraft System (UAS) flown in Temporary Flight Restriction (TFR) or with waiver to provide above disaster operations
- Electro-Optical (EO) visible data feed from large UAS back to Ground Control Station (GCS) fed into local operations center to support sUAS mission
- sUAS #1 provides thermal and EO imagery to those on the ground
- sUAS #1 data back to GCS, and displayed for operations enter and ground operations
- sUAS #2 provides real-time feed of EO data of landscape around train carriages
- sUAS #2 multispectral data downloaded after mission and uploaded to data visualization tool for operations center
- sUAS #3 provides EO video feed of impacted infrastructure to operations center
- sUAS #3 post-processed data provided three-dimensional (3D) model of bridge

Metrics of success:

- Large UAS streams data back to the operations center to support assessment of full extent.
- sUAS #1 streams back data to the operations center and can move the Field Of View (FOV) based on needs.
- sUAS #1 data helps search and rescue teams to find survivors and optimize their search patterns.
- sUAS #2 finds a fuel leak and can map its spread or can provide a second search and rescue team.
- sUAS #3 responds to damaged infrastructure and allows the ground team to determine where to send personnel to ensure the safety of the building/bridge.
- Safe flight operations with three sUAS and one large UAS operating and data streaming back.
- All sUAS flew under Part 107 and Visual Line of Sight (VLOS) to Extended Line of Sight (EVLOS) is maintained.
- Geotagged images and video collected to reconstruct the event in a virtual environment for post-mission assessment of the event.

1.2 CONOP Quad Chart: Train Derailment @ Burlington, Vermont and impacted local infrastructure

1.2.1 Mission Purpose/Objectives

Purpose: A train derails as it approaches the Burlington, Vermont Amtrak station and then hits the local infrastructure. Need to perform search and rescue on the derailed carriages and assess safety of the railroad infrastructure.

Goals: Large UAS keeps continued eyes on the area and crash site to get data to operations center. Local sUAS Part 107 pilots respond and provide data. Mobile sUAS responds to needs of operations center and get data on the event and support ground operators. Ground teams can used sUAS #1 data to target search. sUAS #2 support team to rapidly assess if fuel leak and need to mitigate. sUAS #3 collect data to rapidly assess safety of local infrastructure and target mitigation for further disaster. Communications between the multiple UAS flight teams. Operations Center communicates with pilots in command and get sUAS to move field of view based on observations seen. Get mobile sUAS to move to area of impact.

Objectives: Large UAS with real-time data to GCS and onto operations center used to provide airborne surveillance from above the derailment event and view the full extent of the disaster. sUAS #1 gets visible (EO) and thermal eyes on the derailed train and data can be used by ground teams to target their search for survivors. Data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. sUAS #2 is flown to provide multispectral data around the crash site so that the ground teams can determine if fuel leaked from the train. Can be the second UAS for search and rescue. As with sUAS #1, data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. sUAS #3 is the response UAS to damaged infrastructure, like buildings and bridges. Data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. Real-time data sent back to support assessment of infrastructure to send response teams and if further disaster could be averted. Evaluate how sUAS missions can respond to large UAS operations and data analysis. Evaluate how 107 pilots can respond to needs of State and/or City agencies. Evaluate how ground teams will react to data from sUAS and optimize search for survivors, mitigate fuel leaks, and ensure damaged infrastructure is safe. Collected data and images can be used to build models of the crash environment to support future analysis post missions.

1.2.2 Mission Procedures/Approach

Large UAS: Rapid response take-off from Burlington airport

Beyond line of sight (BVLOS) operations

Flown from nearby runway to then have holding pattern above Burlington Station

Multiple hours of flying to provide high altitude eyes on disaster

Visual Flight Rules (VFR)/Instrument Flight Rules (IFR) conditions as will be BVLOS - able to fly in full range of conditions

sUAS #1: Search and Rescue sUAS flown around train crash

Part 107 waiver and Special Government Interest (SGI) waiver; VLOS operations

Eyes on train from EOEO/thermal; Data to ground teams to help assess focus areas

Can adapt flight to needs of ground teams

sUAS #2: Manual sUAS operations: Supports assessment of any fuel leak from train crash

Pattern defined by operations team to track any leak and map the surrounding area

VLOS with Part 107 or SGI waiver

VFR conditions [IFR if event limits visual observer from keeping VLOS]

sUAS #3: Manual sUAS operations response to damaged infrastructure, such as buildings and/or bridges

Ability to respond to any location requested by operations team

Aim to stay as VLOS but may need EVLOS or BVLOS

1.2.3 Mission Results

Observations: Recording of full extent of the event from a large UAS whose flight pattern aims to provide continued data collection. At least three sUAS used. sUAS #1 is to support ground teams for search and rescue with EO and thermal sensors. Real-time data streamed back and captures images and video for reconstruction of scenes after missions. sUAS #2 is a mobile system with EO/thermal/multispectral [Visible, Red-edge, and near-infrared combined] payload and flown at low altitude around the crash site to support assessment of any fuel leaks on the local landscape. As with sUAS #1 real-time feeds and raw images collected to support post flight product generation. sUAS #3 provides UAS capabilities to map damaged infrastructure like buildings and bridges. Real-time feeds back and images/videos collected to support the team to reconstruct the scenes to build virtual models for damage assessment.

Real-time Mission Products: Large UAS: EOEO/thermal video feeds back to operations center. sUAS #1: EO/thermal videos back to operations and those on the ground for search and rescue. sUAS #2: Multispectral [EO with visible+Red-edge+near-infrared] videos back to operations center to assess if fuel leaks. sUAS #3: EOEO feeds back to allow real-time assessment of infrastructure. Data from all UAS displayed in geospatial interface to superimpose on other available data from state, federal, and local agencies.

Post-Mission [fast response] Products: Three-dimensional models of the data from sUAS #1 and #3 to support virtual inspection of the train crash and any damaged infrastructure. This allows those in operations to analyze the events without having to be placed in the middle of the SAR response and damage mitigation of the infrastructure.

1.2.4 Mission Milestones

Outcomes/Actionable Intelligence

Large UAS able to fly under TFR or waiver to provide above disaster operations

EO data feed from large UAS back to GCS ⇒ Feed into local operations center to support sUAS mission sUAS #1 provides thermal and EO imagery to those on the ground

sUAS #1 data back to GCS ⇒ Displayed for operations center + for those ground operations

sUAS #2 provides real-time feed of EO data of landscape around train carriages

sUAS #2 multispectral data downloaded after mission ⇒ uploaded to visualization tool for operations center

sUAS #3 provides EO video feed of impacted infrastructure to operations center

sUAS #3 post-processed data provided three-dimensional model of bridge

Metrics of success

Large UAS streams data back to the incident center to support assessment of full extent.

sUAS #1 streams back data to operations center and can move field of view based on needs.

sUAS #1 data helps SAR teams to find survivors and optimize their search patterns.

sUAS #2 finds a fuel leak and can map its spread; or can provide a second SAR team.

sUAS #3 responds to damaged infrastructure and allows the ground team to determine where to send personnel to ensure the safety of the building/bridge.

Safe flight operations with three sUAS and one large UAS operating and data streaming back.

All sUAS flew under Part 107 and VLOS to EVLOS is maintained.

Geotagged images and video collected to reconstruct the event in a virtual environment for post-mission assessment of the event.

1.3 Situation

1.3.1 Overview

Purpose of the mission: A train derails as it approaches the Essex-Junction Amtrak junction and station and hits the local infrastructure. Need to perform search and rescue on the derailed carriages and assess safety of the railroad infrastructure.

Goals: Large UAS: EO and thermal payload that provides higher altitude observations on the disaster event (Longer endurance; BVLOS; Support sUAS #2 to look for fuel/oil spillage); sUAS #1: EO and thermal payload that can get close to the carriages to support ground SAR (SAR for survivors; Short campaigns; Targeted to support ground operations). sUAS #2: Multispectral payload (EO visible or visible near-infrared, VNIR) to assess for fuel/oil spill from the derailed carriages (Rapid response; Ability to classify environment rapidly). SUAS #3: EO payload for bridge inspection and any other impacted infrastructure (build 3D models; Real-time high resolution EO data to support assessment of the safety of infrastructure)

UAS mission Lead: University of Vermont team as operations lead working with State emergency operations center.

- Overall: University of Vermont at incident command. Communicate with flight team leads

- Large UAS
    - Flight team lead with crew
    - Flight from Burlington airport
    - Stays at higher altitude)
  - sUAS #1
    - Pilot in command (PIC) with visual observer (VO) and specialist team member to relay observations to other UAS
    - Manual flights: PIC can change route based on needs of SAR for survivors
    - Communications with sUAS #2 and #3 as well as operations center
  - sUAS #2
    - PIC with VO and specialist team member to relay observations to other UAS
    - Manually flown, adapt routes based on event; Classify land around train in real-time
    - Communications to sUAS #1 and operations center
  - sUAS #3
    - PIC and VO and specialist team member to relay observations to other UAS
    - Manually flown, Work with response to support mapping infrastructure
    - Communications to sUAS #12 and operations center

1.3.2 Location

Location

Essex Junction-Burlington Train Station, Vermont

Latitude of Railway Junction: 44.4926° N

Longitude of Railway Junction: 73.1102° W

Burlington International Airport, Vermont

Latitude of Airport: 44.4719550ºN

Longitude of Airport: 73.1532761ºW

ICAO: BTV   ICAO: KBTV   FAA LID: BTV

https://www.airnav.com/airport/KBTV

All Maps in Appendix 3

1.4 Systems

Location: Central Operations

- Coordination with flight teams and Burlington emergency operations center
- ACUASI - Director Cahill and Director of Operations Adkins for large UAS
- University of Vermont team to support operations
- Local Emergency Management Response team, Burlington Airport representatives, Air Boss, FAA, and FEMA representatives

Large UAS

- SeaHunter/Sentry type from Burlington airport

- Endurance for multiple hours per flight
- Full GCS system
- Pilots and support crew for large UAS
    - External Pilot, Crew Chief, Internal Pilot, and Supplemental Pilot
    - Additional operator to manage data feed from onboard payload
- Minimum Payload
    - Optical and thermal payload integrated for nadir viewing
- Flight pattern to stay above train terminal and City of Burlington and within TFR

sUAS #1

- Vertical Take-off and Landing (VTOL)
- Endurance for 30 - 45 mins per flight
- Operations center determines best location to launch sUAS
- Flight team
    - Part 107 PIC + VO
    - Engineering support [if possible as VO]
- Minimum Payload
    - EO with thermal: c
- Need a waiver/permission to get a higher altitude, > 400 ft.

sUAS #2

- Vertical Take-off and Landing (VTOL)
- Endurance for 30 - 45 mins per flight
- Flight team
    - Part 107 PIC + VO
    - Engineering support [if possible as VO]
- Minimum Payload
    - EO, thermal, and multispectral (RGB, VNIR combined)
    - Support mapping of any fuel
    - Pointable with fixed nadir option
    - View can react to needs of operations center
- Sufficient battery capacity for multiple flights
- Onboard systems to support low altitude flying to get data on event
- Fly within TFR that would be in place over derailment

sUAS #3

- VTOL
- Endurance for 30 - 45 mins per flight
- Flight team
    - Part 107 PIC + VO
    - Engineering support [if possible as VO]
- Minimum Payload
    - EO and thermal
    - Capture sufficient data to produce 3D model after mission
    - View can react to needs of operations center

- Sufficient battery capacity for multiple flights
- Onboard systems to support low altitude flying to get data on event
- Fly within TFR that would be in place over derailment

1.5 Mission

Disaster:

A train derails as it approaches the Essex-Junction Amtrak junction and station and hits the local infrastructure. Need to perform search and rescue on the derailed carriages and assess safety of the railroad infrastructure.

Observations

Recording of full extent of the event from a large UAS whose flight pattern aims to provide continued data collection. At least three sUAS used. sUAS #1 is to support ground emergency operations teams for search and rescue with EO and thermal sensors. Real-time data streamed back and captured images and video for reconstruction of scenes after missions. sUAS #2 is a mobile system with EO/thermal/multispectral (RGB with VNIR) payload and flown at low altitude around the crash site to support assessment of any fuel leaks on the local landscape. As with sUAS #1 real-time feeds and raw images collected to support post flight product generation. sUAS #3 provides UAS capabilities to map damaged infrastructure like buildings and bridges. Real-time feeds back and images/videos collected to support the team to reconstruct the scenes to build virtual models for damage assessment.

Response mission:

Trail derailment at Essex-Junction Amtrak junction and station. Report of train derails as it comes into station and potential fuel leaks and impacted buildings and bridges. Need observations of the event from higher altitude, search for survivors, assess impact of fuel leaks on the landscape and potential damage to local infrastructure.

Stakeholders:

Burlington International Airport; FAA; Amtrak and Essex-Junction Amtrak junction and station, State of Vermont Department of Transportation, FEMA; Community of Essex, Vermont, and Local operations center. All need observations of the event and ability to support ground operations.

Goals:

Get large UAS up to keep continued observations on the area and crash site to get data to the operations center; Local sUAS Part 107 pilots respond and provide data. Demonstrate that the mobile sUAS can respond to needs of the operations enter and get data on the event and support ground emergency managers. Ground teams can used sUAS #1 data to target search. sUAS #2 support team to rapidly assess if fuel leak and need to mitigate. sUAS #3 collect data to rapidly assess safety of local infrastructure and target mitigation for further disaster. Show communications between the multiple UAS flight teams and that the operations center Air Boss can communicate with PICs and get sUAS to move field of view based on observations seen; get mobile sUAS to move to area of impact.

Objectives:

Large UAS with real-time data to GCS and onto the operations center used to provide airborne surveillance from above the derailment event and view the full extent of the disaster. sUAS #1 gets visible and thermal observations on the derailed train and data can be used by ground teams to target their search for survivors. Data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. sUAS #2 is flown to provide multispectral data around the crash site so that the ground teams can determine if fuel leaked from the train. Can be the second UAS for search and rescue. As with sUAS #1, data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions.

sUAS #3 is the response UAS to damaged infrastructure, like buildings and bridges. Data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. Real-time data sent back to support Department of Transportation (DOT) and other emergency managers to assess safety of infrastructure to send response teams and if further disaster could be averted. Evaluate how sUAS missions can respond to large UAS operations and data analysis. Evaluate how 107 pilots can respond to needs of State and/or City agencies. Evaluate how ground teams will react to data from sUAS and optimize search for survivors, mitigate fuel leaks, and ensure damaged infrastructure is safe. Collected data and images can be used to build 3D models of the crash environment to support future analysis post missions.

Real-time Mission Products:

- Large UAS - EO/thermal video feeds back to operations center
- sUAS #1: EO/thermal videos back to operations center and those on the ground for SAR
- sUAS #2: Multispectral (EO with VNIR) videos back to operations center to assess if fuel leaks
- sUAS #3: EO feeds back to allow real-time assessment of infrastructure
- Data from all UAS displayed in geospatial interface to superimpose on other available data from state, federal, and local agencies.

Post-Mission (fast response) Products:

Three dimensional models of the data from sUAS #1 and #3 to support virtual inspection of the train crash and any damaged infrastructure. This allows those in the operations center to analyze the events without having to be placed in the middle of the SAR response and damage mitigation of the infrastructure.

1.6 Execution

1.6.1 Operations Plan

1st flight up to support search and rescue for survivors

sUAS #1

- Search and Rescue sUAS flown around train crash
- Part 107 waiver and SGI; VLOS operations
- Observations of the train from EO/thermal data
- Data provided to ground teams to help assess focus areas
- PIC can adapt flight to needs of ground teams
- Follow pre-flight, during, and post-flight checklist for sUAS, need for VO

2nd flight - will take time to respond, provide large scale mapping of extent

Large UAS

- Rapid response take-off from Burlington International airport
- BVLOS operations
- Flown from nearby runway to have holding pattern above crash site
- Multiple hours of flying to provide high altitude observations on disaster
- VFR with option for IFR to support BVLOS
- Able to fly in full range of conditions
- Follow pre-flight, during, and post-flight checklist for large UAS like SeaHunter/Sentry

3rd flight up to fly around derailment and provide data on impact to landscape

sUAS #2

- Manual sUAS operations
- Supports assessment of any fuel leak from train crash
- Pattern defined by operations center to track any leak and map the surrounding area
- VLOS with Part 107 or SGI waiver
- VFR conditions (IFR if event limits VO from keeping VLOS)
- Follow pre-flight, during, and post-flight checklist for sUAS, need for VO

4th flight up as sUAS to map impacted infrastructure like unstable bridge/building

sUAS #3

- Manual sUAS operations
- Response to damaged infrastructure, such as buildings and/or bridges
- Ability to respond to any location requested by operations or DOT directly
- Aim to stay as VLOS but may need EVLOS or BVLOS

1.6.2 Data collection, processing, and dissemination

Large UAS

Full extent of derailment event (both final location of train and all impact)

- Data in flight:
    - High Precision GPS locations and time synchronization
    - Flight routes and logs
    - Geotagged optical and multispectral infrared imagery over disaster area
    - Optical setup to support overlay FOV videos onto geospatial tool (Full Motion Video, FMV)
    - Optical data streamed to GCS and onto EM Ops Center
    - On-board storage of data, downloaded upon landing and processed
- Products post flight:
    - Geotagged video with overlaid field of view on geospatial visualization tool
    - Time tagged video to follow missions and compare to other sUAS data

sUAS #1

SAR aircraft that maps train crash and supports ground operations

- Data in flight:
    - High Precision GPS locations and time synchronization
    - Flight routes and logs
    - Geotagged optical and thermal infrared video feeds
    - Optical setup to support overlay FOV videos onto geospatial tool (FMV)
    - Optical data streamed to PIC, GCS, and EM Ops Center
    - On-board storage of data, downloaded upon landing and processed
    - On-board dedicated communications to support ground and air operation
- Products post flight:
    - Geotagged video with overlaid field of view on geospatial visualization tool
    - Time tagged video to follow missions and compare to other sUAS data
    - Sufficient data to build 3D models of crash site

sUAS #2

Low altitude flights; Targeted to map any fuel leaks

- Data in flight:
    - High Precision GPS locations and time synchronization
    - Flight routes and logs
    - Geotagged multispectral imagery
    - Geotagged EO video feeds
    - Optical setup to support overlay FOV videos onto geospatial tool (FMV)
    - On-board storage of data, downloaded and processed
- Products post flight:
    - Geotagged video with overlaid field of view on geospatial visualization tool
    - Time tagged video to follow missions and compare to other sUAS data
    - Sufficient data to build 3D models of crash site

sUAS #3

Infrastructure damage assessment aircraft; Targeted to support EM Ops Center

- Data in flight:
    - High Precision GPS locations and time synchronization
    - Flight routes and logs
    - Geotagged optical and thermal video feed
    - Optical setup to support overlay FOV videos onto geospatial tool (FMV)
    - On-board storage of data, downloaded and processed
- Products post flight:
    - Geotagged video with overlaid field of view on geospatial visualization tool
    - Time tagged video to follow missions and compare to other sUAS data

- Sufficient data to build 3D models of crash site

1.7 Administration & Logistics

1.7.1 Planning and local logistics

Large UAS team will have accommodation at a hotel nearby the launching airport. This will provide overnight lodging before and after each flight day. Also, it will allow them to store no mission required equipment to optimize the equipment taken with them for the daily missions. Large UAS team will work with the launching airport to acquire runway access and set up locations for their ground control station. UAS mission teams will ensure that all required waivers are in place to support flight operations. Large UAS will have all permissions to fly from launching airport and within the NAS to the terrorism event. If TFR in place, the flight team lead will liaise with the event air boss to ensure permissions set up to allow large UAS to fly into TFR.

For sUAS, any required Part 107 waivers will be in place before missions start. SGI waiver will be submitted to support all sUAS missions to ensure that sufficient permissions are acquired, if needed, so that they do not need to be submitted during the missions and any time lost. All waivers and permissions in place to support them in any location across Burlington, Vermont, and surrounding region. All required communications will occur between all PICs and local air traffic control tower. All NOTAM's will be provided to the wider aviation community.

1.7.2 Hazards/Risk

The following information provides specific hazards that may occur from supporting the emergency response to the train derailment event.

Hazard #1: Loss of time synchronization between UAS used in response

- Risk**:** This hazard would be caused by incorrect timing of missions [multiple aircraft] to match through centralized communications. Possible effects are aircraft taking off at the wrong time and data not comparable for evaluation of the disaster event.
- Mitigation**:** Before all the missions start, the flight crews will ensure that aircraft systems and GCSs are synchronized so that data can be compared. Between flights, the crew will re-assess the time synchronization of their systems and be in communications with the central team to ensure operations occur at the time specified in the CONOP.

Hazard #2: Large UAS is unable to stay airborne or takes too long to launch

- Risk: This hazard comes from the time taken to get the large UAS airborne to collect data thus limiting higher altitude observations of the event. Also, it can be caused by a need to refuel and therefore no high-altitude observations of the response. Possible effects are no higher altitude data to keep eyes on the full extent of the event and/or act as a communications hub.
- Mitigation: The large UAS team will react as quickly as they are requested to support the disaster response. They will know the available airports that they can use for their flight operations and will have their own flight checklists for flight operations. The large UAS team that assets are closest to the disaster response will be contacted first to ensure fast response. The disaster response team will know the available large UAS teams that are approved to support a disaster response. The large UAS flight crew will inform the ICS lead/air boss on their currently available fuel and time that they can stay airborne.

Hazard #3: Crew unable to provide visual observations for sUAS flight

- Risk: This hazard comes from a required flight time of the sUAS missions extending beyond the visual observation capabilities of the crew and there is no VLOS plan in place. Possible effects are that a mission must end and cannot support operations or a sUAS cannot be tracked and so a Return To Base (RTB) is required to ensure the crew can keep a visual on it and airspace.
- Mitigation: Before the mission starts, the PIC will determine the maximum distance that a VO can see to ensure VLOS operations based on the conditions at the time of flight. The VO will continue to stay in communication with the PIC to ensure that they can confirm that they can see the aircraft and the airspace around the operations. If there is a deviation of the planned flight route, then the PIC will ensure that the VO can still see the aircraft and if no onboard DAA system is in place and no waiver to allow BVLOS operations then the new route will not occur, and the aircraft will stay on its course that ensure VLOS operations.

Hazard #4: Crew unable to ensure safe operations over people and/or property

- Risk: This hazard comes from the flight crew being unable to ensure safe flight operations when there are people and/or property below the flight route. Possible effects are a crash of the UAS with people/property or a need to RTB because the PIC cannot ensure safe flight operations.
- Mitigation: Before the mission starts, the PIC will define all the backup landing zones in case there is an issue with the flight operations. The VO will continue to track the aircraft and airspace and inform the PIC if they are unable to continue this role. If there is a loss of the aircraft by the VO, then the PIC will invoke a DLI or RTB depending on the location and proximity to people and property. The flight mission will have all required permissions to allow them to fly over people and the environment below the flight path.

Hazard #5: Loss of power and navigational connection to large UAS in NAS

- Risk: This hazard comes from a loss of power and control of the large UAS providing higher altitude eyes on the response. Possible effects are no higher altitude data to keep eyes on the full extent of the event and/or act as a communications hub and a RTB or uncontrolled descent of the UAS.
- Mitigation: Mitigation would include assigning ditch points for the UAS in the CONOP, so the team is prepared for safe landings, if unable to return to home. The crew member responsible for mission team safety and the ground control station will inform the PIC or mission manager on loss of power. Depending on the vehicle capabilities, it may not be possible to reach a prescribed ditch point during a power loss. However, if the vehicle can reach the ditch point, these points should be monitored for pedestrian/ground traffic to ensure safe landing is possible. VOs in place for VLOS operations will be used to support the PIC in understanding any risks on the ground below the aircraft's location when power is lost. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flights alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights.

1.7.3 Community outreach and connections

All Operations: Burlington Community and Airport; Incident command team if a statewide operations center has been setup; Connection to FAA in area

Large UAS: Communications with Burlington International airport sUAS: Will need at least three sets of missions. Coordinated on who will fly each mission.

1.7.4 Disaster response mission specific information

State of Vermont Emergency Management Plan - Base Plan

1.7.5 Mission Summary

Disaster:

A train derails as it approaches the Burlington, Vermont Amtrak station and then hits the local infrastructure. Need to perform search and rescue on the derailed carriages and assess safety of the railroad infrastructure.

Objectives:

Provide airborne observations over the events at the crash site and any impacted infrastructure, continuous eyes from higher altitude. Search and rescue support to optimize application of ground teams; Eyes on the events from lower altitude and can move based on EM Ops Center needs; Data to assess if any fuel leaks from train crash and track leak dispersal; mobile sUAS capabilities to support ground teams to assess safety of damage infrastructure from the crash.

Flight Missions:

Large UAS flown to provide overview of full disaster extent (Continued observations that support emergency response to determine sUAS location and observational needs). Three sUAS missions flown to: (1) provide EO/thermal data of events to support ground SAR teams; (2) manually operated sUAS that collect data on any fuel leaks from crash and second SAR sUAS; and (3) rapid response capabilities to react damaged infrastructure like bridges and support team to assess safety and mitigate further disaster.

Metrics of success:

- Large UAS streams data back to the operations center to support assessment of full extent.
- sUAS #1 streams back data to the operations center and can move the field of view (FOV) based on needs.
- sUAS #1 data helps search and rescue teams to find survivors and optimize their search patterns.
- sUAS #2 finds a fuel leak and can map its spread or can provide a second search and rescue team.
- sUAS #3 responds to damaged infrastructure and allows the ground team to determine where to send personnel to ensure the safety of the building/bridge.
- Safe flight operations with three sUAS and one large UAS operating and data streaming back.
- All sUAS flew under Part 107 and VLOS to EVLOS is maintained.
- Geotagged images and video collected to reconstruct the event in a virtual environment for post-mission assessment of the event.

1.8 Command & Signal

Aim: *This section should provide an overview of the command and communication systems to be used. This supports anyone reviewing and evaluating the CONOP to efficiently assess those sufficient communications are in place to connect the UAS flight crew with additional organizations connected to and supporting the disaster response and/or preparedness.*

For some of the details included in this section, the plans will cross reference to the ORA, as they will be mitigation plans to ensure safe flight operations and minimize the risk of hazards that can impact flight operations.

Include details on:

- Type of communications tools used to connect PIC, Observer, and other crew members
- Security measures in place to protect the flight crew
- Hand-off process, where appropriate, between the PIC and visual observer(s)
- Flight team lost link and emergency procedures to ensure safe flight operations
- Communication tools use to connect the flight team and local ATC
- Note: for each communication tool to be used, this section should also include signals used such as radio frequencies, flight control frequencies, etc.

1.9 Supplementary appendices to accompany CONOP

1.9.1 Appendix 1: Operational Details – One Pager

Mission and Disaster Preparedness/Response

Train Derailment @ Burlington, Vermont and impacted local infrastructure

Mission Purpose/Objectives

Purpose : A train derails as it approaches the Burlington, Vermont Amtrak station and then hits the local infrastructure. Need to perform search and rescue on the derailed carriages and assess safety of the railroad infrastructure.

Goals : Large UAS keeps continued eyes on the area and crash site to get data to operations center. Local small UAS Part 107 pilots respond and provide data. Mobile small UAS responds to needs of operations center and get data on the event and support ground operators. Ground teams can used small UAS #1 data to target search. Small UAS #2 support team to rapidly assess if fuel leak and need to mitigate. Small UAS #3 collect data to rapidly assess safety of local infrastructure and target mitigation for further disaster. Communications between the multiple UAS flight teams. Operations Center communicates with pilots in command and get small UAS to move field of view based on observations seen. Get mobile small UAS to move to area of impact.

Objectives : Large UAS with real-time data to ground control station (GCS) and onto operations center used to provide airborne surveillance from above the derailment event and view the full extent of the disaster. Smll UAS #1 gets visible (electo-optical) and thermal eyes on the derailed train and data can be used by ground teams to target their search for survivors. Data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. Small UAS #2 is flown to provide multispectral data around the crash site so that the ground teams can determine if fuel leaked from the train. Can be the second UAS for search and rescue. As with small UAS #1, data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. Small UAS #3 is the response UAS to damaged infrastructure, like buildings and bridges. Data collected of sufficient accuracy to reconstruct the crash site to virtually assess the event after the missions. Real-time data sent back to support assessment of infrastructure to send response teams and if further disaster could be averted. Evaluate how small UAS missions can respond to large UAS operations and data analysis. Evaluate how 107 pilots can respond to needs of State and/or City agencies. Evaluate how ground teams will react to data from small UAS and optimize search for survivors, mitigate fuel leaks, and ensure damaged infrastructure is safe. Collected data and images can be used to build models of the crash environment to support future analysis post missions.

Mission Results

Observations : Recording of full extent of the event from a large UAS whose flight pattern aims to provide continued data collection. At least three small UAS used. Small UAS #1 is to support ground teams for search and rescue with electro-optical and thermal sensors. Real-time data streamed back and captures images and video for reconstruction of scenes after missions. Small UAS #2 is a mobile system with electro-optical/thermal/multispectral [Visible, Red-edge, and near-infrared combined] payload and flown at low altitude around the crash site to support assessment of any fuel leaks on the local landscape. As with small UAS #1 real-time feeds and raw images collected to support post flight product generation. Small UAS #3 provides UAS capabilities to map damaged infrastructure like buildings and bridges. Real-time feeds back and images/videos collected to support the team to reconstruct the scenes to build virtual models for damage assessment.

Real-time Mission Products : Large UAS: Electro-optical/thermal video feeds back to operations center. Small UAS #1: Elecro-optical/thermal videos back to operations and those on the ground for search and rescue. Smal UAS #2: Multispectral [electro-optical with visible+Red-edge+near-infrared] videos back to operations center to assess if fuel leaks. Small UAS #3: Electro-optical feeds back to allow real-time assessment of infrastructure. Data from all UAS displayed in geospatial interface to superimpose on other available data from state, federal, and local agencies.

Post-Mission [fast response] Products : Three-dimensional models of the data from small UAS #1 and #3 to support virtual inspection of the train crash and any damaged infrastructure. This allows those in operations to analyze the events without having to be placed in the middle of the SAR response and damage mitigation of the infrastructure.

Mission Procedures/Approach

Large UAS : Rapid response take-off from Burlington airport
Beyond line of sight (BVLOS) operations
Flown from nearby runway to then have holding pattern above Burlington Station
Multiple hours of flying to provide high altitude eyes on disaster
Visual Flight Rules (VFR)/Instrument Flight Rules (IFR) conditions as will be BVLOS - able to fly in full range of conditions

Small UAS #1 : Search and Rescue small UAS flown around train crash
Part 107 waiver and special government interest (SGI) waiver; Visual line of sight (VLOS) operations
Eyes on train from electro-optical/thermal; Data to ground teams to help assess focus areas
Can adapt flight to needs of ground teams

Small UAS #2 : Manual small UAS operations: Supports assessment of any fuel leak from train crash
Pattern defined by operations team to track any leak and map the surrounding area
VLOS with Part 107 or SGI waiver
VFR conditions [IFR if event limits visual observer from keeping VLOS]

Small UAS #3 : Manual small UAS operations reponse to damaged infrastructure, such as buildings and/or bridges
Ability to respond to any location requested by operations team
Aim to stay as VLOS but may need extended-VLOS (EVLOS) or BVLOS

Mission Milestones

Outcomes/Actionable Intelligence
Large UAS able to fly under temporary flight restriction (TFR) or waiver to provide above disaster operations
Electro-optical data feed from large UAS back to GCS ⇒ Feed into local operations center to support small UAS mission
Small UAS #1 provides thermal and electro-optical imagery to those on the ground
Small UAS #1 data back to GCS ⇒ Displayed for operations center + for those ground operations
Small UAS #2 provides real-time feed of electro-optical data of landscape around train carriages
Small UAS #2 multispectral data downloaded after mission ⇒ uploaded to visualization tool for operations center
Small UAS #3 provides electro-optical video feed of impacted infrastructure to operations center
Small UAS #3 post-processed data provided three-dimensional model of bridge

Metrics of success
Large UAS streams data back to the incident center to support assessment of full extent.
Small UAS #1 streams back data to operations center and can move field of view based on needs.
Small UAS #1 data helps search and rescue (SAR) teams to find survivors and optimize their search patterns.
Small UAS #2 finds a fuel leak and can map its spread; or can provide a second SAR team.
Small UAS #3 responds to damaged infrastructure and allows the ground team to determine where to send personnel to ensure the safety of the building/bridge.
Safe flight operations with three small UAS and one large UAS operating and data streaming back.
All small UAS flew under Part 107 and VLOS to EVLOS is maintained.
Geotagged images and video collected to reconstruct the event in a virtual environment for post-mission assessment of the event.

1.9.2 Appendix 2: Flight Checklists

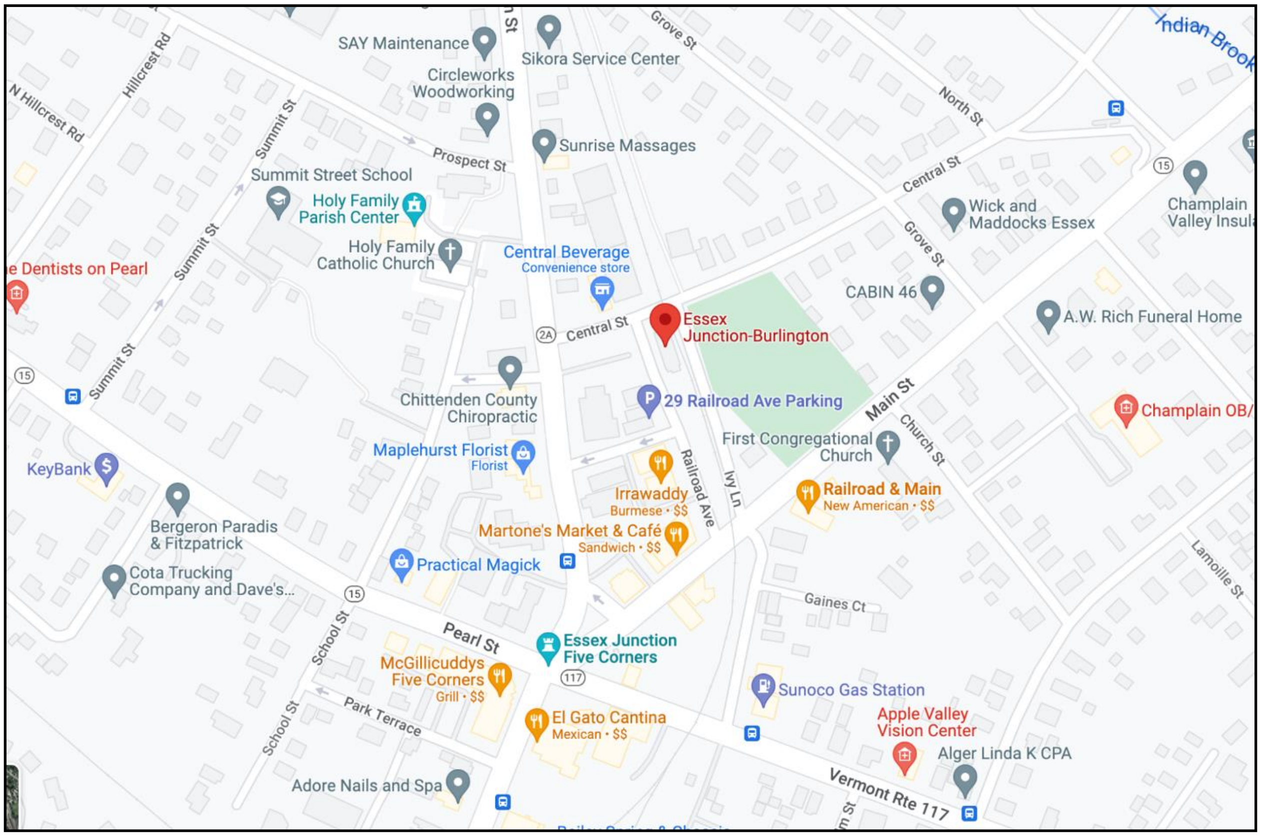
Aim: *This appendix collects all flight checklists the mission team would complete pre-, during, and post-flight while at the mission location as well as pre- and post-operation before arriving and after leaving the mission location. Each flight checklist is included in a supplementary document. These checklists are to supplement the maintenance checklists that would go with the organization leading the missions for the disaster response and/or preparedness that they use to ensure the safety of their aircraft and equipment. These maintenance checklists will likely be a part of the organization's own safety assessment process.*

Include details on:

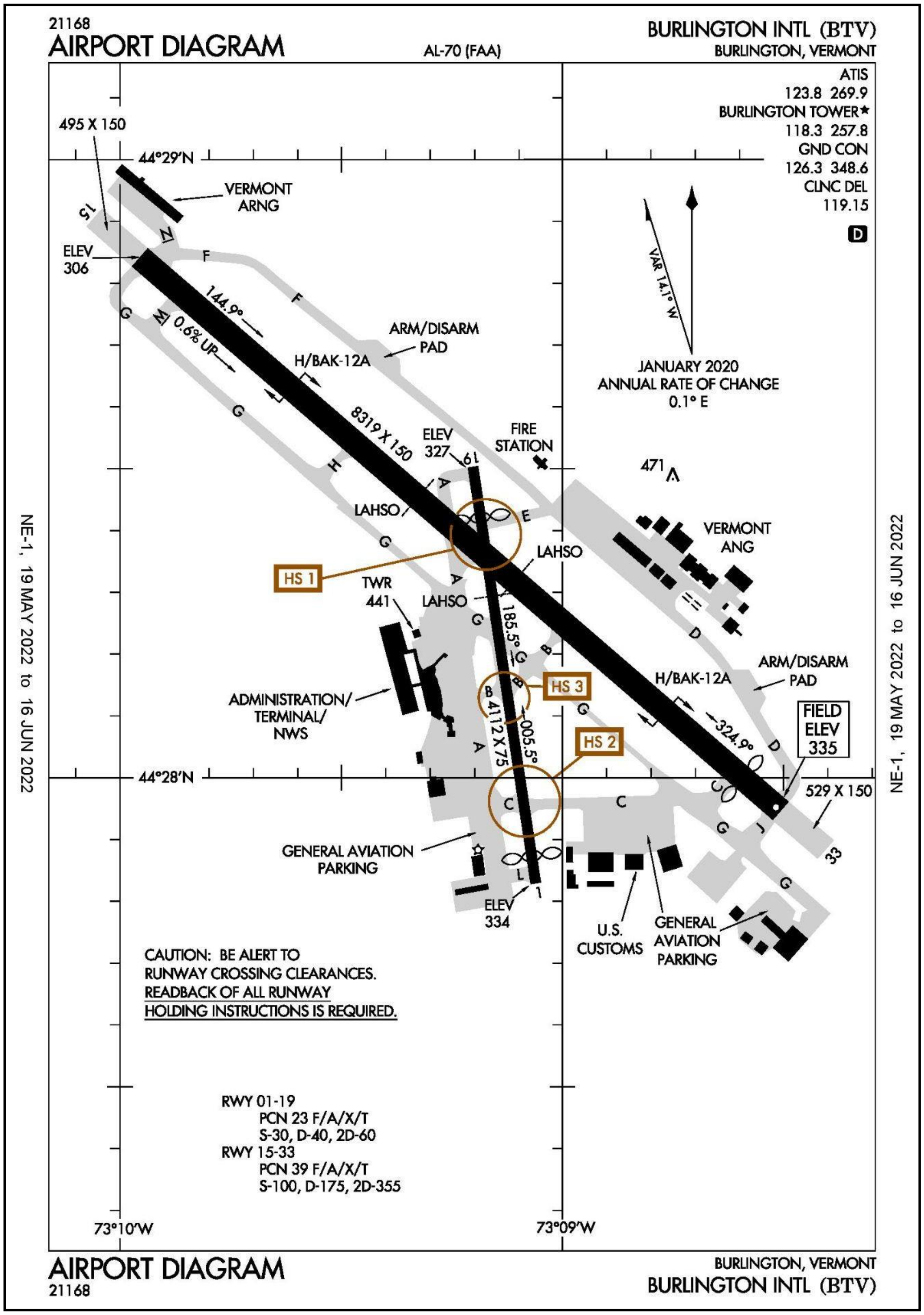
- Before CONOP development: Site Survey (details on assessment of mission location)
- Before Operations: Mission checklist (complete at home for lead organization)
- Pre-deployment: Checklist to complete prior to leaving for mission site
- Deployment: Checklists for flight operations, once arrived at mission site
- Pre-flight: Checklist to follow prior to flight including example of flight readiness review
- Post-flight: Checklists to follow including log sheet
- Post-mission: Checklists to follow at the end of all flights for the mission

1.9.3 Appendix 3: Additional Requirements

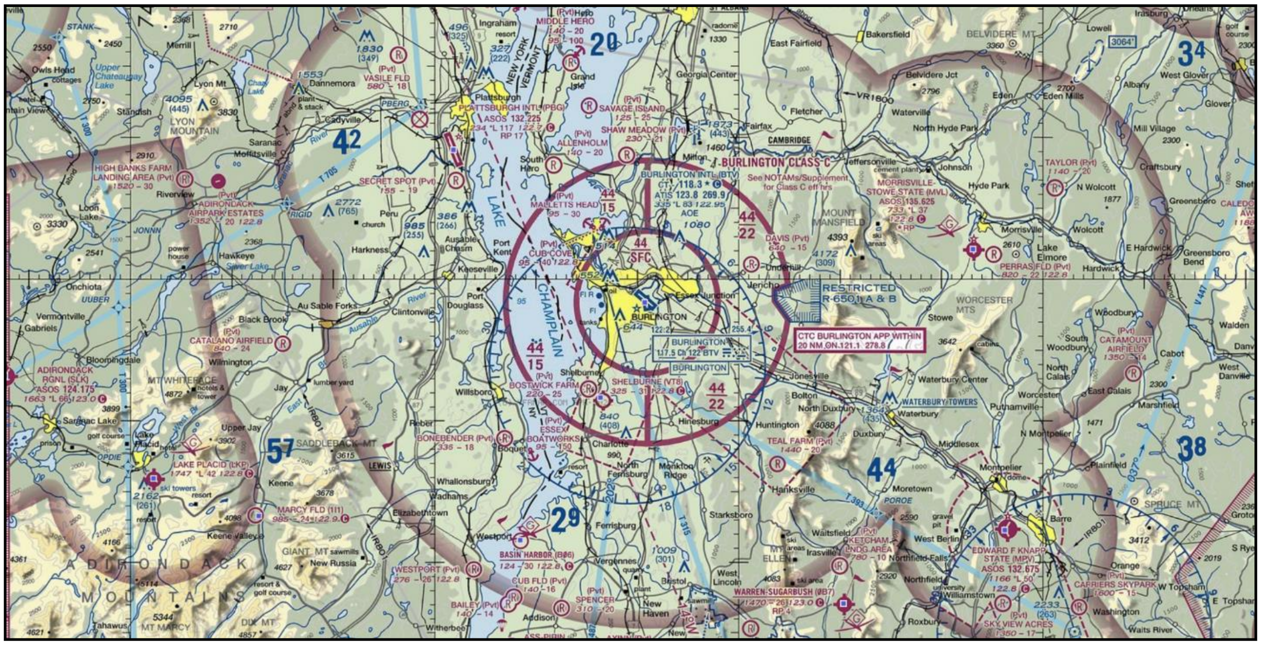
<u>Amtrak Train Junction within community of Essex, Vermont</u>



Airport Map

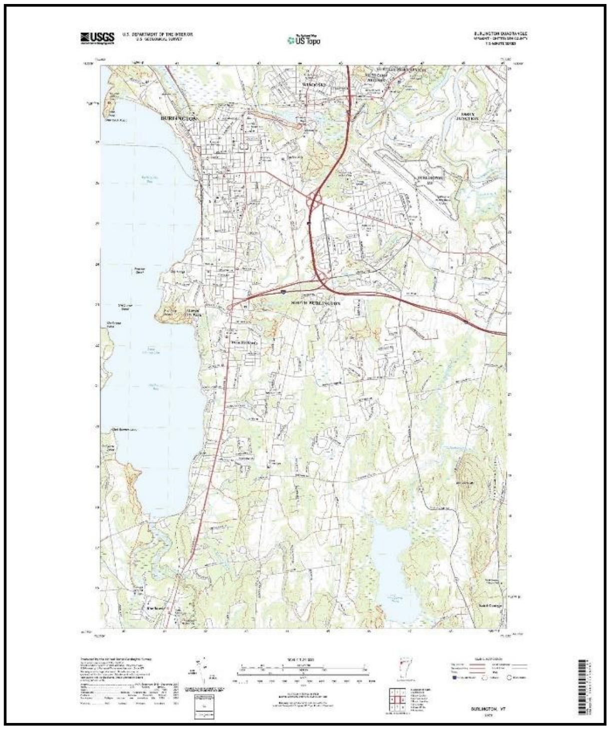

21168
AIRPORT DIAGRAM
AL-70 (FAA)
BURLINGTON INTL (BTV)
BURLINGTON, VERMONT
ATIS
123.8 269.9
BURLINGTON TOWER★
118.3 257.8
GND CON
126.3 348.6
CLNC DEL
119.15
495 X 150
44°29'N
VERMONT
ARNG
ELEV
306
144.9°
0.6% UP
H/BAK-12A
ARM/DISARM
PAD
JANUARY 2020
ANNUAL RATE OF CHANGE
0.1° E
VAR 14.1° W
8319 X 150
ELEV
327
FIRE
STATION
471
LAHSO
VERMONT
ANG
HS 1
TWR
441
LAHSO
185.5°
HS 3
ADMINISTRATION/
TERMINAL/
NWS
H/BAK-12A
ARM/DISARM
PAD
4112 X 75
005.5°
HS 2
324.9°
FIELD
ELEV
335
44°28'N
529 X 150
GENERAL AVIATION
PARKING
ELEV
334
U.S.
CUSTOMS
GENERAL
AVIATION
PARKING
CAUTION: BE ALERT TO
RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY
HOLDING INSTRUCTIONS IS REQUIRED.
RWY 01-19
PCN 23 F/A/X/T
S-30, D-40, 2D-60
RWY 15-33
PCN 39 F/A/X/T
S-100, D-175, 2D-355
73°10'W
73°09'W
NE-1, 19 MAY 2022 to 16 JUN 2022
AIRPORT DIAGRAM
21168
BURLINGTON, VERMONT
BURLINGTON INTL (BTV)

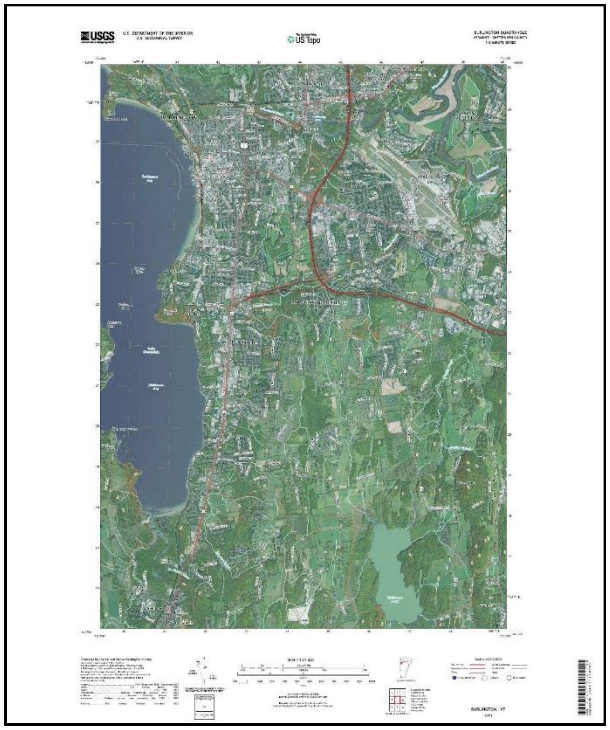
[Sectional Chart](#)



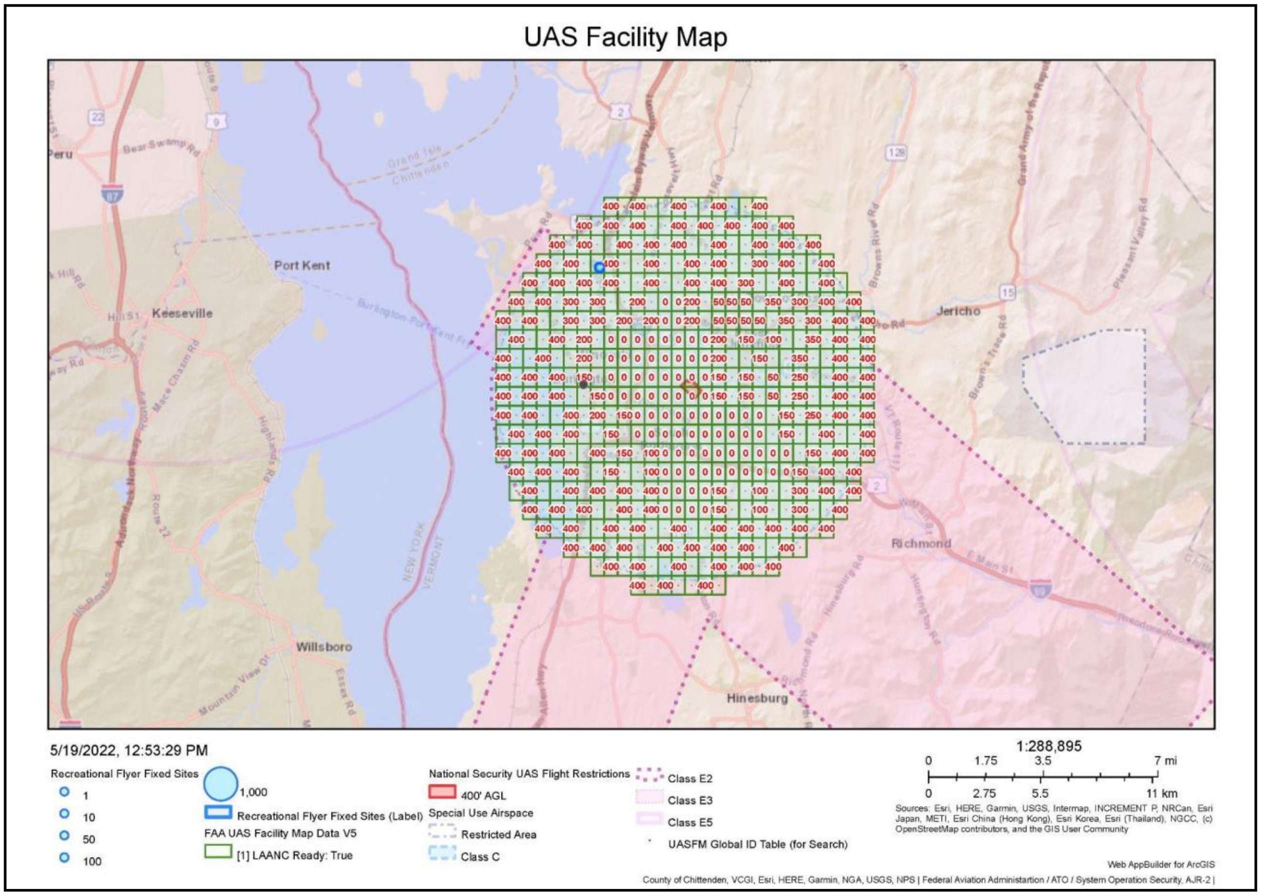
[United States Geological Survey (USGS) 7.5-minute topographic map](#)

[Burlington](#)





[Low Altitude Authorization and Notification Capability (LAANC) Facility Maps]



1.9.4 Appendix 4: Special Government Interests (SGI) Process Documentation

- FAA Order JO7200.23B
  Processing of UAS Requests. Effective: July 14, 2020
  - Page 16 to 19: Chapter 6. 14CFR Part 91, COA Processing
  - Page 17 – SGI information: The SGI process will be managed by Systems Operations Security as per FAA Order JO 7210.3

- FAA Order JO7210.3CC
  Facility Operation and Administration. Effective: June 17, 2021
  - Page 469: Section 21-5-4. UAS SGI Addendum Request Process and Coordination
  - System Operations Support Center (SOSC) Contact Phone Number - 202-267-8276
- FAA Request Form for Expedited SGI Waiver or Authorization for UAS Operation – Form # SOSC 2020/02/20 1125Z

1.9.5 Appendix 5: Data Archive Plan

Processing specifications

- Imagery and video collected at maximum resolution
- Sufficient overlap to support Structure from Motion processed
- Full motion video captured where possible from available payload

File formats

- Detailed descriptions: https://www.ogc.org/docs/is
- EO visible and multispectral visible - near-infrared imagery
  - Joint Photographic Experts Group (JPEG): containing lossy and compressed data
  - Tag Image File Format (TIFF): store raster graphics and image information
- Broadband thermal infrared imagery
  - Radiometric JPEG: JPEG and TIFF for thermal data
  - Stores Temperature data as well as RGB JPEG of thermal data
- EO visible and multispectral visible - near-infrared video
  - MPEG-4 format [MP4, note MOV from EO visible on dual camera system]
  - High compression international audio-visual coding standard
- Broadband thermal infrared video
  - SEQ/FFF - Proprietary FLIR video formats that store images and thermal data
  - MOV - MPEG 4 video container file
- Point clouds - LiDAR data
  - LAS (binary file format) or LAZ (compressed LAS file)
- Geospatial data - GEOTIFF
  - Standard file for GIS with embedded geolocation data
- Google Keyhole Markup Language (KML)
  - KML (default Google Earth geospatial format)
  - KMZ (compressed KML file format)

- Geographic JavaScript Object Notation (GEOJSON)
    - GEOJSON (coordinates as text in JavaScript Object Notation form
- Shapefile (SHP)
    - SHP (feature geometry), SHX (shape index position), DBF (attribute data)
    - PRJ (projection system metadata), XML (associated metadata)

Data archiving locations

- In-Flight:
    - Onboard storage of all data as well as through specific GCS
    - Data streamed through GCS to operations center to support secondary archive
- Post-Flight:
    - Online secure file storage per UAS and per mission [password protected]
    - Folders for raw sensor data as well as flight logs and route data

Folders to store post-processed data and all planning documents

1.9.6 Appendix 6: Rationale behind each section in CONOP

Situation

High level situation awareness and sufficient information to clearly define each element.

Template items

- *Organization's business (manufacturer, operator, system integrator, etc.).*
- *Geographic operating boundaries (lack of specifics implies very broad NAS access).*
- *Describe if launch/ fly/ recover only over private property with owner's permission.*
- *Define the minimum and maximum operating altitude of the vehicle.*
- *Describe if operating within or beyond Visual Line of Sight (VLOS).*
- *Define command and control link.*
- *Provide details on dimensions and materials for vehicle design.*
- *Identify the vehicle's maximum cruise speed and maximum operating gross weight.*
- *Describe Proposed Airspace Classes (A, B, C, D, E, F, etc.).*
- *Define the Proposed Operating Airspace (character aspects – regardless of class).*
- *Describe location of the control station.*

Mission:

Sufficient, clear, and concise statement of what the flight team and lead organization and/or stakeholders for the disaster response mission request want to accomplish. Provide the most important large-scale information and provide sufficient information and clearly define each element.

- *Describe the intended mission of the UAS (surveillance, response, preparedness, etc.).*

Execution:

Thoroughly state how you will "execute" the mission and provide sufficient information and clearly define each element.

- *Identify Airspace Considerations (peculiarities and congestion, special use, etc.)*
- *Give information on Launch and Recovery Details / Location(s)*
- *Identify and describe the vehicle's proximity to people, infrastructure, and surface vehicles*
- *Identify and describe the vehicle's proximity to other NAS users*
- *Identify whether you want to Flight into Known Icing (FIKI)*
- *Identify meteorological conditions you want to operate in Visual / Instrument conditions*
- *Identify the flight rules you want to operate in Visual / Instrument Flight Rules*
- *Describe whether your geographic and airspace boundaries are physically contiguous*
- *Identify Automation Level (occasional autopilot, 100% autonomous, manual control, etc.)*
- *Identify minimum crew and support personnel*
- *Identify the role(s) of the crew and support personnel*
- *Identify whether you will fly over people not involved in the operation*
- *Identify any requests for airspace be blocked off for your exclusive use*
- *Identify your operator/vehicle ratio (1:1, etc.)*
- *Identify day and/or night operations*
- *Describe your plan for safety of Operator(s) and Observer(s)*
- *Describe the training level of each team member*

Command & Signal:

Sufficiently provide information of their plans involving command and communication functions between different portions of the UAS and stakeholders. Clearly describe how you will command and signal amongst the various components of the entire system (vehicle, control station, control link, observers, etc.)

- *Describe Communication between Operator, Observer, Crew Members (visual, radio, etc.)*
- *Describe the Electronic Security of the Control Link*

- *Describe the Physical Security of the operator and control station*
- *Describe real time situational awareness features*
- *Describe the # of operators, and hand-off between control*
- *Describe Lost Link Procedures or loss of Positive Control*
- *Describe Communication Expectations with Air Traffic Control*
- *Describe Emergency Procedures*

Administration & Logistics:

Adequately provide the information or instructions pertaining to how and with whom they will coordinate to conduct the operations.

- *Details on Community Outreach (Flying / Non-Flying Public, municipalities, airports, etc.)*
- *Describe when if flight routes will be filed with Air Traffic Control (VFR / IFR)*
- *Identify Liaisons with Air Traffic Control*
- *Identify MISHAP Reporting Procedures*
- *Identify when NOTAMs will be posted*