Final Report
ASSURE A28: Disaster Preparedness and Response Using UAS
Attachment 8 – Concept of Operations (CONOPS) for Volcano

June 1, 2022

NOTICE

LEGAL DISCLAIMER

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TABLE OF ACRONYMS

AGL	Above Ground Level
ARTCC	Air Route Traffic Control Center
AVO	Alaska Volcano Observatory
BVLOS	Beyond Visual Line of Sight
CONOP	Concept of Operation
DAA	Detect and Avoid
DOI	Department of the Interior
EO	Electro-Optical
FAA	Federal Aviation Administration
GCS	Ground Control Station
GEOJSON	Geographic JavaScript Object Notation
HD	High definition
HDF5	Hierarchical Data Format
Hz	Hertz
IFR	Instrument Flight Rules
JPEG	Joint Photographic Experts Group
KML	Keyhole Markup Language
NAS	National Airspace System
NOTAM	Notice to Airmen
NWS	National Weather Service
ORA	Operational Risk Assessment
PIC	Pilot in Command
RH	Relative Humidity
RTB	Return to Base
SfM	Structure from Motion
SGI	Special Government Interest
SHP	Shape file
SOSC	System Operations Support Center
TFR	Temporary Flight Restriction
TIFF	Tag Image File Format
UAF	University of Alaska Fairbanks

UAS	Uncrewed/Unmanned Aircraft System
USGS	United States Geological Survey
VAAC	Volcanic Ash Advisory Center
VFR	Visual Flight Rules
VLOS	Visual Line of Sight
VO	Visual Observer
VTOL	Vertical Take-Off and Landing

ATTACHMENT 8 - CONCEPT OF OPERATIONS (CONOPS) FOR VOLCANO

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 **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)

Eruption of Spurr volcano in Cook Inlet, Alaska

Summit events and downwind ash cloud passing over Anchorage, Alaska

Volcanic Plume and Downwind Cloud Hazard Assessment

Operation:

Volcanic Plume and Downwind Cloud Hazard Assessment. Need observations at the summit of Spurr and downwind ash and gasses as they pass over Anchorage, Alaska

Duration of Operation:

Approximately a day

Outcomes/Actionable intelligence:

- Large UAS able to fly in U.S National Airspace System (NAS) and into and out of a Temporary Flight Restriction (TFR) area
- Large UAS Electro-Optical (EO) visible data feed goes back to operations center and/or volcano observatory headquarters
- Small UAS #1 provides observations of the active region of the volcano at the summit
- Small UAS #1 sends back EO visible and thermal data.
- Small UAS #1 products include digital elevation model and thermal map of the summit
- Small UAS #2 responds to need for a downwind vertical profile with location based on weather prediction data
- Small UAS #2 samples the downwind cloud and data is transmitted to volcano observatory and local national weather service team
- All UAS data pushed to online site for operations center and local volcano observatory to examine/display as well as post-event archive for analysis

Metrics of success:

- Large UAS streams data back to the operations center to support assessment of full extent
- Small UAS #1 streams back data to support those on ground to mitigate hazards
- Small UAS #2 samples downwind clouds and data to reaches operations center including volcano observatory and those forecasting ash cloud dispersal
- Small UAS #2 flight crew and pilot in command responds to commands from the operations center on where observations are needed
- Safe flight operations with two small UAS operating and with data streaming back
- Both small UAS flew under Part 107 with waivers and so Visual Line Of Sight (VLOS) is maintained
- Small UAS #2 takeoffs and lands in the community. Flights over people and infrastructure
- Part 107 waiver requested and approved for small UAS #2 to support > 400 ft profiles

1.2 CONOP Quad Chart: Volcanic Plume and Downwind Cloud Hazard Assessment

1.2.1 Mission Purpose/Objectives

Purpose: Volcanic eruption with plume and clouds putting population/infrastructure at risk.

Goals: Sample the ash/gas concentrations to assess hazard levels, thermal and EO mapping of summit to support observatory and ground observations

Objectives: Large UAS operations with real-time data or post-processed samples. Small UAS operations at summit to sample plume and map active regions. Small UAS downwind missions to measure ash and gas concentrations

1.2.2 Mission Procedures/Approach

Large UAS: Beyond Visual Line of Sight (BVLOS) High altitude observations

Early morning take-off, Flown from runway into TFR at summit

Day of flying to reach summit

Visual Flight Rules (VFR)/Instrument Flight Rules (IFR) conditions as will be BVLOS and traveled from runway to volcano

Sample plume through predefined routes and re-sample based on data

Small UAS #1: Summit mapping, if possible

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

Flown in the TFR region - match when large UAS overhead and small UAS downwind

VFR conditions

Sample the plume and map the summit in EO and thermal

Small UAS #2: West Anchorage: between volcano and Anchorage airport

Downwind operations in community; Site chosen based on predicted cloud locations

Time of flights to match small UAS #1 missions and/or other observations

VLOS with Part 107 waiver if needed based on time of day/location/altitude

VFR conditions

Vertical profile of ash/gas concentrations

1.2.3 Mission Results

Observations: Ash/gas concentrations to understand risk to airports, aviation travelling in and out of the region. Data to be collected for volcano observatory and U.S. National Weather Service for forecasting. Optical and thermal imaging of the summit region to build three-dimensional (3D) models and orthomosaics.

Products: Orthomosaics in optical and thermal wavelengths of summit as well as 3D models where Structure from Motion (SfM) is possible given plume opacity. Ash and gas concentrations along specific routes and manual sampling. 3D profiles through the plume and downwind clouds. Vertical profiles at point locations with Vertical Take-Off and Landing (VTOL) small UAS.

1.2.4 Mission Milestones

Outcomes/Actionable Intelligence

Large UAS able to fly in National Airspace System and into and out of TFR

Large UAS EO data feed goes back to operations center and/or volcano observatory

Small UAS #1 able to reach active region

Small UAS #1 able to send back EO data, produce surface model and thermal map of the summit

Small UAS #2 able to respond to need for downwind vertical profile, gain permission

Small UAS #2 able to sample cloud and get data back to volcano observatory and National Weather Service (NWS)

All UAS data pushed to online website for operations enter and volcano observatory to examine/display

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 support those on ground to mitigate hazards.

Small UAS #2 samples downwind clouds; data for all involved in operational response

Small UAS #2 pilot in command responds to commands from the incident center on where observations are needed.

Safe flight operations with two small UAS operating in close vicinity with data streaming back.

Both small UAS flew under Part 107 waivers and so VLOS is maintained.

Small UAS #2 takeoffs and land in the local community and collects vertical profile

SGI/Part 107 waiver given for small UAS #2 to support > 400 ft vertical profiles

1.3 Situation

1.3.1 Overview

Purpose of mission: To provide data and observations of an ongoing volcanic eruption. Observations required at the summit of the eruptive events including any ground hazards and eruption plumes as well as downwind sampling of ash clouds

Goals: Large UAS flown at higher altitudes to support long endurance observations of the eruptive events. Small UAS #1 and its flight crew placed near to the volcanic eruptive zone (likely the summit) to provide data on any ground hazards and to sample any eruption plume emitted from the activity zone. Small UAS #2 and crew placed downwind of the dispersing clouds from the eruption to sample them to support the observatory and weather service in predictions of the potentially hazardous airborne particulates and gasses.

Collect observations of the ash and gas content of the plume and downwind clouds that can be hazard to population centers, aircraft, and infrastructure.

UAS mission lead: University of Alaska Fairbanks (UAF) Alaska Center for Unmanned Aircraft Systems Integration team with large UAS working with support from local volcano observatory and the UAS team from the Department of Interior to provide the small UAS.

Large UAS: High altitude observations of the event

- Flight team with crew
- Flight from Anchorage International Airport
- Stays at higher altitudes throughout the event

Small UAS #1: Summit mapping of eruptive products, both ground and airborne

- Pilot in command and Visual Observer (VO)
- EO visible and thermal sensors
- Data feeds through ground control station to operations center/volcano observatory
- Vertical profile collection as well as mapping of the eruptive zone

Small UAS #2: Downwind sampling of dispersing clouds

- Pilot in command and VO
- Specialist team member to operate the sampling sensors within the payload
- Additional EO visible sensor to provide observations of surrounding area
- Site chosen based on predictions of ash and gas cloud dispersal
- Vertical profile data collection rather than regional mapping

1.3.2 Location

Ted Stevens Anchorage International Airport, Alaska

Latitude: 61.1740847° N Longitude: 149.9981375° W

IATA: ANC ICAO: PANC FAA LID: ANC

https://www.airnav.com/airport/PANC All maps and documents in Appendix 3

1.4 Systems

Central Operations

- Team members coupled to AK Interagency Plan for Volcanic Ash Episodes - 2017 edition
- Coordination of flight teams
    - Anchorage/Alaska emergency operations center or airport
- UAF lead points of contact for large UAS operations
- Alaska Volcano Observatory (AVO)
    - United States Geological Survey (USGS)-based Scientist in Charge
    - UAF-based Coordinating Scientist
    - AVO-based Duty Remote Sensor
- USGS Volcano Hazards Program and Alaska Science Center
    - Current: Tina Neal
    - Provides links to Department of Interior (DOI) and their UAS team
- National Oceanic and Atmospheric Administration/National Weather Service
    - Link to Anchorage NWS office
    - Link to Anchorage Volcanic Ash Advisory Center (VAAC)
    - Link to Air Resources Laboratory and Dispersion Modeling
- Anchorage Air Traffic Control Center (ARTCC)
    - Link to Alaska Aviation Weather Unit

1st flight: High altitude observations for mapping the event

- Large UAS
    - SeaHunter/Sentry type
    - Ted Stevens Anchorage International Airport, Alaska (PANC)
    - Endurance for multiple hours per flight, up to 4 hours per mission
    - 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
        - EO feed is sent back to Ground Control Station (GCS) and onto operations center
        - Optical and thermal payload integrated for nadir viewing
        - Onboard Ash and volcanic gas detection system
    - Flight pattern to stay above airport and within temporary flight restriction

2nd flight: At summit observations with volcano observatory/USGS personnel

- Small UAS #1
    - VTOL capacity
    - Endurance for summit data collection
    - Flight team
        - Team members safety skills to access at-risk volcanic region
        - USGS/DOI Part 107 Pilot in Command (PIC) + (VO)

        - Engineering support (if possible as VO)
    - Minimum Payload
        - EO with thermal: Pointable with fixed nadir option
        - 1Hz volcanic gas sensor and/or ash particle counter sensor
        - 1Hz Relative Humidity (RH), Temperature (T), and pressure (P) sensor
    - Power capacity for multiple summit missions
    - Waiver/permission setup to support higher altitude than 400 ft Above Ground Level (AGL)

<u>3rd flight: downwind observations in local community</u>

- <u>Small UAS #2</u>
    - VTOL capacity
    - Endurance for multiple flights for data collection
    - Flight team
        - Part 107 PIC + VO
        - Engineering support (if possible as VO)
    - Minimum Payload
        - EO with thermal: Pointable with fixed nadir option
        - 1Hz volcanic gas sensor and/or ash particle counter sensor
        - 1Hz RH, Temperature (T), and pressure (P) sensor
    - Power capacity for multiple summit missions and > 1000 ft AGL
    - Waiver/permission setup to support higher altitude than 400 ft AGL

1.5 Mission

<u>Disaster:</u>

Volcanic eruption from Mount Spurr Volcano has been detected by the Alaska Volcano Observatory. There is a need for summit observations and analysis of the downwind ash clouds and its potential to put population/infrastructure at risk.

<u>Observations:</u>

Recording of full extent of the event from a large UAS whose flight pattern provides continued data collection. Two small UAS used. Small UAS #1 will be flown at and around the summit of Mount Spurr volcano to provide EO visible and thermal infrared observations of the activity as well as measurements of the ash and gas concentrations in the erupting plume. Small UAS #2 is a mobile system and will be used to provide vertical profiles of atmospheric conditions downwind of the volcano and over the City of Anchorage. This data will be used to detect the ash and gas concentrations of the population of Anchorage and nearby air traffic routes. It will provide observations to support those forecasting the dispersal of the ash and gas clouds as well as the potential for hazardous air quality in the region.

<u>Response mission:</u>

The Alaska Volcano Observatory uses ground based and spaceborne observations to monitor the volcanoes across the State. They have raised the color code for Mount Spurr to Red and Warning as a new eruption has been detected. To improve their prediction of the ongoing hazard, they need observations of the summit activity. In addition, the observatory and the NWS provide predictions of the location of the dispersing ash and gas clouds from the eruption to support decision making. Satellite data is useful to validate the modeling results, but they need point location and vertical profiles of observations as well. Also, these vertical profile observations will support the decision makers to assess the air quality in the area and how the hazardous clouds could impact the local community, infrastructure, and aviation community. A mobile UAS system is needed to adapt its flight location to support these observational needs.

Stakeholders:

Anchorage International Airport, Alaska Volcano Observatory, NWS Alaska, State/Federal/Local government on ash/gas cloud levels for air quality impact on population

Goals:

Large UAS keeps continued observations of the eruption and surrounding area (communities and infrastructure) and to get data to the operations center; small UAS #1 accesses the summit region and collects data on the ongoing activity while ensuring safety of the flight crew; Mobile small UAS #2 flight crew can position themselves to locations where the volcano observatory and/or NWS requires observations to validate the model and/or determine air quality levels. Small UAS #1 can collect data and send back through its ground control station to the local volcano observatory to develop three-dimensional visible and thermal maps of the summit. Vertical profile observations from the summit provide details on ash, gas, RH, T, and P of the plumes to support the modeling teams and the observatory scientists to improve understanding of potential activity changes. Small UAS #2 provides vertical profiles of up to 1000 ft AGL or to extent of VO capacity to measure ash, gas, RH, T, and P in the local boundary layer. This data will support the modeling community to validate their predictions and potential calibrate them to support future model forecasts. This data in near-real-time will support decision makers to assess the local to regional air quality and determine if warnings are required downwind of the volcano.

Objectives:

Large UAS flies from Anchorage International Airport in the National Airspace System and into and out of TFR area over and around the volcano. Large UAS streams data back to the incident center to support assessment of full extent as well as ensuring real-time streams also reach volcano observatory. Small UAS #1 reaches active regions and streams back EO data to support those on ground to mitigate hazards. Small UAS #1 flight crew can rapidly produce surface model and thermal map of the summit Small UAS #2 responds to the need for downwind vertical profile, gains required permissions, samples downwind clouds; and provides data for all involved in operational response. This flight crew will need to be mobile and adaptable to the needs of the event. Small UAS #2 samples cloud and ensure data gets back to volcano observatory and NWS. All UAS data pushed to an online website for operations enter and volcano observatory to examine/display. Safe flight operations with two small UAS operating in close vicinity with data streaming back. Both small UAS flew under Part 107 waivers and so VLOS is maintained. Small UAS #2 takeoffs and land in the local community and collect vertical profiles. SGI/Part 107 waiver given for small UAS #2 to support > 400 ft vertical profiles Demonstrate how a small UAS flight crew can rapidly respond, move location at the needs of an emergency management team, and apply their flight protocols.

Real-time Mission Product:

- Large UAS: EO and thermal video feeds back to the operations center.
- Small UAS #1: EO and thermal video and unfiltered ash/gas/RH/T/P data.
- Small UAS #2: EO and thermal video and unfiltered ash/gas/RH/T/P data.
- 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:

- Orthomosaics in optical and thermal wavelengths of summit
- Summit three-dimensional models where structure from motion (SfM) is possible given plume opacity
- Ash and gas concentrations along specific routes and manual sampling
- Three dimensional profiles through the plume and downwind clouds
- Vertical profiles at point locations with VTOL small UAS.

1.6 Execution

1.6.1 Operations Plan

Large UAS supports the event and 2 small UAS at lower altitudes, with their specific missions. One at the volcano summit and one in Anchorage, with location defined by volcano observatory and/or national weather service needs.

Large UAS

- Rapid response take-off from local airport, such as Ted Stevens Anchorage International Airport, Alaska (PANC)
- Mission will be flown under BVLOS operations
- A holding pattern above Mount Spurr Summit and Anchorage vicinity
- Stay above disaster event for multiple hours
- Provide high altitude observations on disaster
- Fly under instrument flight rules conditions
- Support operations under a full range of atmospheric conditions
- Sample plume through predefined routes and re-sample based on data
- Follow pre-flight, take-off, in-flight, landing, and post-flight checklists for large UAS

Small UAS #1

- This will be a mobile small UAS that collects data from the volcano summit
- Team will be USGS personnel and DOI UAS team members
- Operations will occur in hazardous area, team will need all safety training for helicopter travel and working around active volcano
- Operations will have Part 107 and SGI waiver to support operations in restricted areas like TFR
- Sample the plume and map the summit in optical and thermal
- Follow pre-flight, during, and post-flight checklist for sUAS, need for VO

<u>Small UAS #2</u>

- Pop-up flights across Anchorage at the needs of those in disaster response
- Small UAS Part 107 operations with waivers to ensure flight operations over people, infrastructure, and > 400 ft AGL
- Locations selected based on predicted ash and gas cloud dispersal
- Time of flights to match small UAS #1 missions and/or other ground observations
- Flown to collect vertical profile of ash/gas concentrations as well as atmospheric conditions
- Onboard EO visible and thermal sensors to support analysis of dispersing clouds
- Follow pre-flight, during, and post-flight checklist for small UAS, need for VOs

1.6.2 Data collection, processing, and dissemination

<u>Large UAS</u>

Full extent of volcanic eruption (Summit and downwind over population and aviation routes)

- Data in flight:
    - High Precision locations and time synchronization of flight
    - Flight routes and logs from crew
    - Ash particulate and concentrations along route from take-off to land
    - Gas concentrations along route from take-off to land
    - Geotagged optical and thermal infrared imagery over the volcano
    - Decimeter res. visible data from High definition (HD) multi-megapixel camera
    - Broadband thermal infrared (7 - 13 μm) data: Minimum 640 x 480 resolution
    - Sampling at 1 Hz for ash particulates (from 0.1 - 100 μm)
    - Sampling at 1 Hz for gas concentrations (sulfur dioxide)
    - Optical setup supports overlay videos onto visualization tool (Full Motion Video)
    - Optical and thermal setup to support SfM processing from data
    - Optical data streamed to GCS
    - On-board storage of data, downloaded upon landing and processed
- Products post flight:
    - Geotagged videos with overlaid field of view on geospatial visualization tool
    - Mosaicked maps from optical and thermal data
    - Three-dimensional profiles of ash particulate data and gas concentrations

<u>Small UAS #1</u>

Mount Spurr Summit Observations

- Data in flight:
  - High Precision locations and time synchronization of flight
  - Flight routes and logs from crew
  - Ash particulate and concentrations along route from take-off to land
  - Gas concentrations along route from take-off to land
  - Geotagged optical and thermal infrared imagery over the volcano
  - Decimeter res. visible data from HD multi-megapixel camera
  - Broadband thermal infrared (7 - 13 μm) data: Minimum 640 x 480 resolution
  - Sampling at 1 Hz for ash particulates (from 0.1 - 100 μm)
  - Sampling at 1 Hz for gas concentrations (sulfur dioxide)
  - Sampling at 1 Hz for atmospheric conditions including RH/P/T
  - Optical setup supports overlay videos onto visualization tool (Full Motion Video)
  - Optical and thermal setup to support SfM processing from data
  - Optical data streamed to PIC
  - On-board storage of data, downloaded upon landing and processed
- Products post flight:
  - Geotagged videos with overlaid field of view on geospatial visualization tool
  - Mosaicked maps from optical and thermal data
  - Three-dimensional profiles of ash and gas concentrations along flight routes
  - Three-dimensional profiles of atmospheric parameters along flight routes

<u>Small UAS #2</u>

Downwind observations over Anchorage

- Data in flight:
  - High Precision locations and time synchronization of flight
  - Flight routes and logs from crew
  - Profile from ground to 1000 ft AGL (~ 330 m AGL)
  - Ash particulate and concentrations along route from take-off to land
  - Gas concentrations along route from take-off to land
  - Geotagged optical and thermal infrared imagery over the volcano
  - Decimeter res. visible data from HD multi-megapixel camera
  - Broadband thermal infrared (7 - 13 μm) data: Minimum 640 x 480 resolution
  - Sampling at 1 Hz for ash particulates (from 0.1 - 100 μm)
  - Sampling at 1 Hz for gas concentrations (sulfur dioxide)
  - Sampling at 1 Hz for atmospheric conditions including RH/P/T
  - Optical setup supports overlay videos onto visualization tool (Full Motion Video)
  - Optical and thermal setup to support SfM processing from data

- Optical data streamed to PIC
- On-board storage of data, downloaded upon landing and processed

- Products post flight:
    - Geotagged videos with overlaid field of view on geospatial visualization tool
    - Mosaicked maps from optical and thermal data
    - Three-dimensional profiles of ash and gas concentrations along flight routes
    - Three-dimensional profiles of atmospheric parameters along flight routes

<u>Post Mission Debrief</u>

- Discussion if metrics for success accomplished
- Performed at end of each day (depending on length of event)
- All flight crews with operations center leads as well as UAS lead organizations (UAF)
- Documented lessons learned and where issues occurred to limit mission success

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 launching airport to acquire runway access and set up location 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 small UAS, any required Part 107 waivers will be in place before missions start. SGI waiver will be submitted to support all small UAS 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. Small UAS #1 will fly at the summit of the volcano. Flight crew will be USGS DOI personnel so that they can access the active region, be flown to the summit with AVO-based helicopters and be trained in how to deal with hanging volcanic activity levels.

Small UAS #2 will be mobile and flown from set locations at the needs of NWS, AVO and local emergency management. Flight team will have their own vehicle and radio/cell communications so that they can move to needed locations. All waivers and permissions in place to support them in any location across western Anchorage and the Kenai Peninsula. All required communications will occur between all PICs and local air traffic control tower. All Notices to Airmen (NOTAMs) will be provided to the wider aviation community.

1.7.2 Hazards/Risk

The following information provides specific hazards that may occur from support the emergency response to the volcano event.

Hazard 1: Large UAS flies from National Airspace System to temporary airspace restriction zone.

- Risk: Large UAS will start off at Anchorage airport and fly in the U.S. NAS and the specific airspace at and surrounding this airport. It will then fly from the NAS, where there could be other crewed and uncrewed systems, into a TFR setup over the eruption from Mount Spurr. Flight team does not have permissions setup with the operations center and therefore will be unable to enter TFR.
- Mitigation: Flight crew and PIC coordinate with the operations center and air boss for emergency response so that they are aware at all times of the location of the large UAS. PIC and flight mission lead will set up all permissions before any missions starts to ensure that the large UAS can respond to all needs of the response and enter and leave the TFR when needed.

Hazard #2: Crew unable to provide visual observations for small UAS #1 flight given plume opacity changes

- Risk: This hazard comes from a required flight time of the small UAS missions extending beyond the visual observation capabilities of the crew as the plume prevents continued visual tracking of UAS and airspace and there is no BVLOS plan in place. Possible effects are that a mission must end and cannot support operations or a small UAS 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 detect and avoid 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 #3: Small UAS #2 is mobile and pushing the limits of VLOS. VO may lose sight of UAS.

- Risk: Manually flown UAS will provide vertical profile observations of dispersing ash clouds and flying under VLOS operations with a VO. The mission may require flying to the maximum extent of observers view and as such would be close to flying outside VLOS. This would then mean that the flight crew does not have a sight on UAS or the airspace around it.
- Mitigation: PIC and VO will be in constant contact to ensure that there is always a visual sighting on UAS and airspace. VO will inform the PIC if the flight route is reaching the extent of their visibility of the aircraft and airspace. PIC will inform operations to see if necessary to push beyond VLOS operations. If so, then extended VLOS will be assessed if possible. If BVLOS is needed, flight crew will determine if UAS has BVLOS capacity and request through SGI on a BVLOS waiver to continue operations.

Hazard #4: Toxic ash and gases concentrations along flight routes

- Risk: This hazard caused by volcanic ash/gas concentrations impacting the aircraft and visibility leads to IFR only conditions. Possible effects resulting from this hazard are a loss of aircraft performance and ability to continue mission.
- Mitigation: PIC will perform controlled flight operations to move the aircraft away from the toxic level of ash and gas. The PIC will assess if the levels of ash and gas in the atmosphere limit the ability of the UAS to operate and the crew to continue to operate. The PIC will determine if a RTB or return to land is required or if the aircraft can continue its operations. The mission PIC will invoke a Divert Land Immediately, which suspends the onward flight path and commands the UAS to land at a designated landing zone, in a controlled manner at the maximum safe descent rate.

Hazard #5: Lack of timing precision between missions prevents data from being compared.

- Risk: There will be one large UAS being flown for the ground support as well as two small UAS teams. Each will be acquiring imagery and videos of the events, ash/gas/atmospheric data as well as recording their flight logs and global positioning system locations of their flights. To cross-compare the data feeds and evaluate the data, each of these systems needs to be time-synchronized. If not, the data will not be able to be compared and prevent cross analysis of the UAS data.
- Mitigation: The PICs and flight crew for each UAS will synchronize their flight clocks and sensor clocks with the same coordinated universal time timing system. This will be continuously monitored throughout the missions and rechecked and recalibrated after each flight. This will ensure that there are minimal time differences between the clocks of all the aircraft and sensors and support like data comparison.

Hazard #6: Eruption intensity dramatically changes while flight occurring

- Risk: This hazard is a result of a rapid change in the volcanic activity that puts the Mount Spurr summit team at risk. Possible effects are a need to evacuate the flight team and/or an aircraft that is at risk from the volcanic activity.
- Mitigation: During this flight, the PIC will ensure that the UAS captures the data needed for the disaster response. The PIC will work with their flight crew to be informed on the future plume and cloud dispersal as well as increase in volcano color code and seismic signals so that they can be prepared to manually fly the aircraft to locations where the observations needed can be collected and/or evacuate their location to find a new, safe site for operations as well as takeoff and landing. If this requires VLOS operations, the crew will review if the permissions are in place to support this type of mission before proceeding.

Hazard #7: Ash/gas clouds move away from flight route for small UAS #2

- Risk: This hazard is a result of the downwind clouds that need to be measured, moving, and dispersing away from small UAS and away from its pre-defined flight route. Possible effects are a flight route that cannot provide observations or runs out of power or would need to fly under BVLOS before collecting all the data.
- Mitigation: During this flight, the PIC will ensure that the UAS can capture the data needed for the disaster response. The PIC will work with their flight crew to be informed on the future

plume and cloud dispersal so that they can be prepared to manually fly the aircraft to locations where the observations needed can be collected. If this requires BVLOS operations, the crew will review if the permissions are in place to support this type of mission before proceeding. The action will ensure safe flight operations and a minimizing of the risk placed on the aircraft and/or flight crew.

1.7.3 Community outreach and connections

- All Operations: Anchorage community and airport through incident command team or a statewide operations center if one that has been setup
- Large UAS: Communications with launching airport for large UAS (Anchorage International airport) and Department of Defense Joint-Base Elmendorf-Richardson given routes around Anchorage and their potential airspace.
- Small UAS #1: Two missions. Coordination between flight teams on who will fly each mission. Coordination with Alaska Volcano Observatory on helicopter flights to reach summit and for knowledge of volcanic activity levels
- Small UAS #2: Coordination with Alaska Volcano Observatory and NWS: Anchorage/VAAC ⇒ ash forecasting.

1.7.4 Disaster response mission specific information

All flights obtain information from Alaska Volcano Observatory on the history of Mount Spurr Volcano. AVO website: https://www.avo.alaska.edu/volcanoes/volcinfo.php?volcname=Spurr.

1992 eruption of Mount Spurr USGS Bulletin Report (#2139) included in safety information for all flight teams.

Details on the different hazards from Alaskan Volcanoes from AVO: Website

Current volcanic activity from AVO: Website

Current volcanic ash advisories from NWS Anchorage VAAC: Website

Current volcanic ash modeling from National Oceanic and Atmospheric Administration Air Resources Lab: Website

Mount Spurr: Crater Peak Cam - Situated near to a AVO seismic station

1.7.5 Mission Summary

Disaster:

Volcanic eruption from Mount Spurr Volcano has been detected by the Alaska Volcano Observatory. There is a need for summit observations and analysis of the downwind ash clouds and its potential to put population/infrastructure at risk. Volcanic eruption from Mount Spurr Volcano has been detected by the Alaska Volcano Observatory. There is a need for summit observations and analysis of the downwind ash clouds and its potential to put population/infrastructure at risk.

Objectives:

Large UAS flies from Anchorage International Airport in the National Airspace System and into and out of TFR area over and around the volcano. Large UAS streams data back to the incident center to support assessment of full extent as well as ensuring real-time streams also reach volcano observatory. Small UAS #1 reaches active regions and streams back EO data to support those on ground to mitigate hazards. Small UAS #1 flight crew can rapidly produce surface model and thermal map of the summit Small UAS #2 responds to the need for downwind vertical profile, gains required permissions, samples downwind clouds; and provides data for all involved in operational response. This flight crew will need to be mobile and adaptable to the needs of the event. Small UAS #2 samples cloud and ensure data gets back to volcano observatory and NWS. All UAS data pushed to an online website for operations enter and volcano observatory to examine/display. Safe flight operations with two small UAS operating in close vicinity with data streaming back. Both small UAS flew under Part 107 waivers and so VLOS is maintained. Small UAS #2 takeoffs and land in the local community and collect vertical profiles. SGI/Part 107 waiver given for small UAS #2 to support > 400 ft vertical profiles Demonstrate how a small UAS flight crew can rapidly respond, move location at the needs of an emergency management team, and apply their flight protocols.

Flight Missions:

Large UAS flown at higher altitudes to support long endurance observations of the eruptive events. Small UAS #1 and its flight crew placed near to the volcanic eruptive zone (likely the summit) to provide data on any ground hazards and to sample any eruption plume emitted from the activity zone. Small UAS #2 and crew placed downwind of the dispersing clouds from the eruption to sample them to support the observatory and weather service in predictions of the potentially hazardous airborne particulates and gasses. Large UAS flown at higher altitudes to support long endurance observations of the eruptive events. Small UAS #1 and its flight crew placed near to the volcanic eruptive zone (likely the summit) to provide data on any ground hazards and to sample any eruption plume emitted from the activity zone. Small UAS #2 and crew placed downwind of the dispersing clouds from the eruption to sample them to support the observatory and weather service in predictions of the potentially hazardous airborne particulates and gasses.

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 support those on ground to mitigate hazards.
- Small UAS #2 samples downwind clouds; data to DEC and ANC airport/NWS/Federal Aviation Administration (FAA)
- Small UAS #2 PIC responds to the incident center on where observations are needed.
- Safe flight operations with two sUAS operating in close vicinity with data streaming back.
- Both small UAS flew under Part 107 + waivers and so VLOS is maintained.
- Small UAS #2 takeoffs and land in the local community and collects vertical profile
- SGI waiver given for Small UAS #2 to support > 400 ft AGL vertical profiles

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 VO(s)
- Flight team lost link and emergency procedures to ensure safe flight operations
- Communication tools use to connect the flight team and local ARTCC
- 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

Volcanic Plume and Downwind Cloud Hazard Assessment

Mission Purpose/Objectives

Purpose: Volcanic eruption with plume and clouds putting population/infrastructure at risk.

Goals: Sample the ash/gas concentrations to assess hazard levels, Thermal and electro-optical mapping of summit to support observatory and ground observations

Objectives: Large UAS operations with real-time data or post-processed samples. Small UAS operations at summit to sample plume and map active regions. Small UAS downwind missions to measure ash and gas concentrations

Mission Results

Observations: Ash/gas concentrations to understand risk to airports, aviation travelling in and out of the region. Data to be collected for volcano observatory and U.S. National Weather Service for forecasting. Optical and thermal imaging of the summit region to build three-dimensional (3D) models and orthomosaics.

Products: Orthomosaics in optical and thermal wavelengths of summit as well as 3D models where structure from motion (SfM) is possible given plume opacity. Ash and gas concentrations along specific routes and manual sampling. 3D profiles through the plume and downwind clouds. Vertical profiles at point locations with vertical take-off and landing (VTOL) small UAS.

Mission Procedures/Approach

Large UAS: Beyond Line of Sight (BVLOS) High altitude osbervations
Early morning take-off, Flown from runway into temporary flight restriction (TFR) @ summit
Day of flying to reach summit
Visual Flight Rules (VFR)/Instrument Flight Rules (IFR) conditions as will be BVLOS and traveled from runway to volcano
Sample plume through predefined routes and re-sample based on data

Small UAS #1: Summit mapping, if possible
Visual Line of Sight (VLOS) operations with Part 107 waiver and special governmental interest (SGI) waiver
Flown in the TFR region - match when large UAS overhead and small UAS downwind
VFR conditions
Sample the plume and map the summit in electro-optical and thermal

Small UAS #2: West Anchorage: between volcano and Anchorage airport
Downwind operations in community; Site chosen based on predicted cloud locations
Time of flights to match small UAS #1 missions and/or other observations
VLOS with Part 107 waiver if needed based on time of day/location/altitude
VFR conditions
Vertical profile of ash/gas concentrations

Mission Milestones

Outcomes/Actionable Intelligence
Large UAS able to fly in National Airspace System and into and out of TFR
Large UAS electro-optical data feed goes back to operations center and/or volcano observatory
Small UAS #1 able to reach active region
Small UAS #1 able to send back electro-optical data, produce surface model and thermal map of the summit
Small UAS #2 able to respond to need for downwind vertical profile, gain permission
Small UAS #2 able to sample cloud and get data back to volcano observatory and NWS
All UAS data pushed to online website for operations enter and volcano observatory to examine/display

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 support those on ground to mitigate hazards.
Small UAS #2 samples downwind clouds; data for all involved in operational response
Small UAS #2 pilot in command responds to commands from the incident center on where observations are needed.
Safe flight operations with two small UAS operating in close vicinity with data streaming back.
Both small UAS flew under Part 107 waivers and so VLOS is maintained.
Small UAS #2 takeoffs and land in the local community and collects vertical profile
SGI/Part 107 waiver given for smll UAS #2 to support > 400 ft vertical profiles

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*

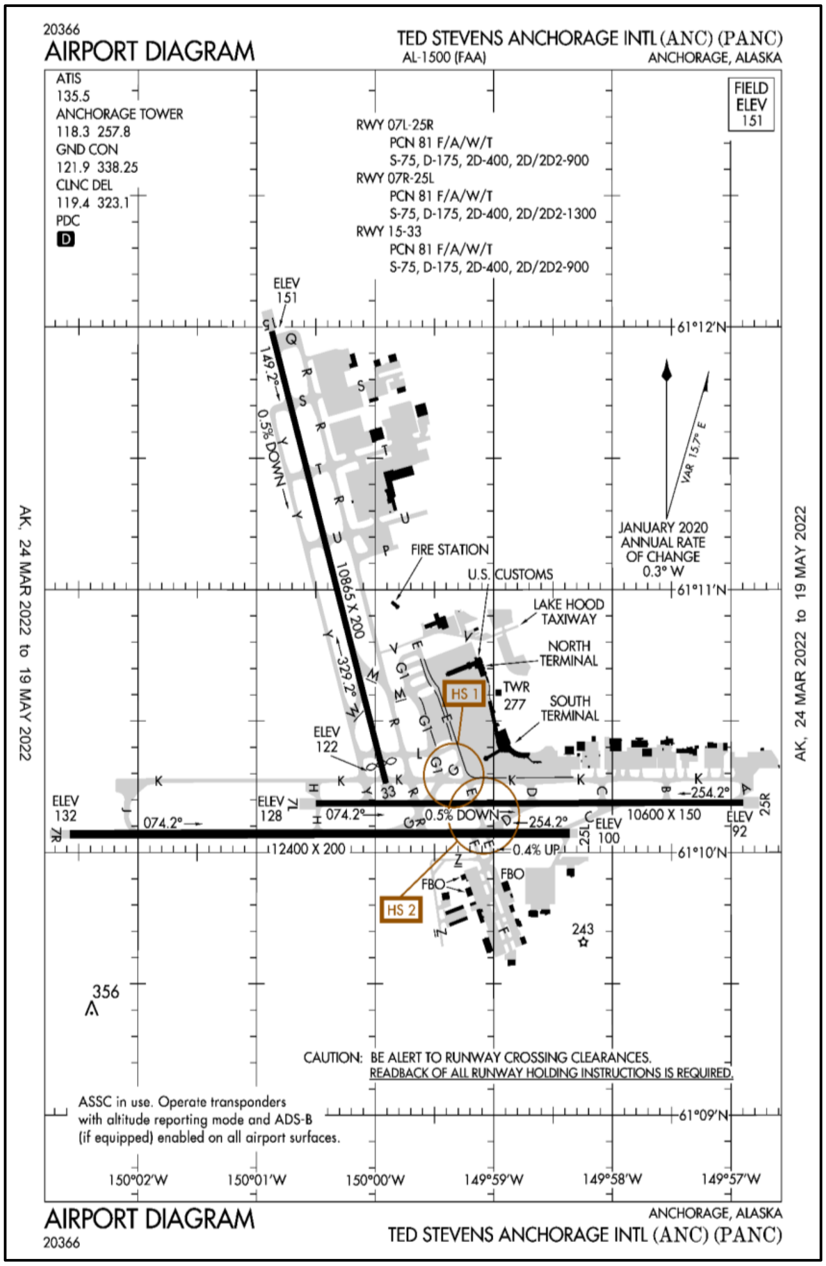
Ted Stevens Anchorage International Airport, Alaska

Latitude: 61.1740847° N Longitude: 149.9981375° W

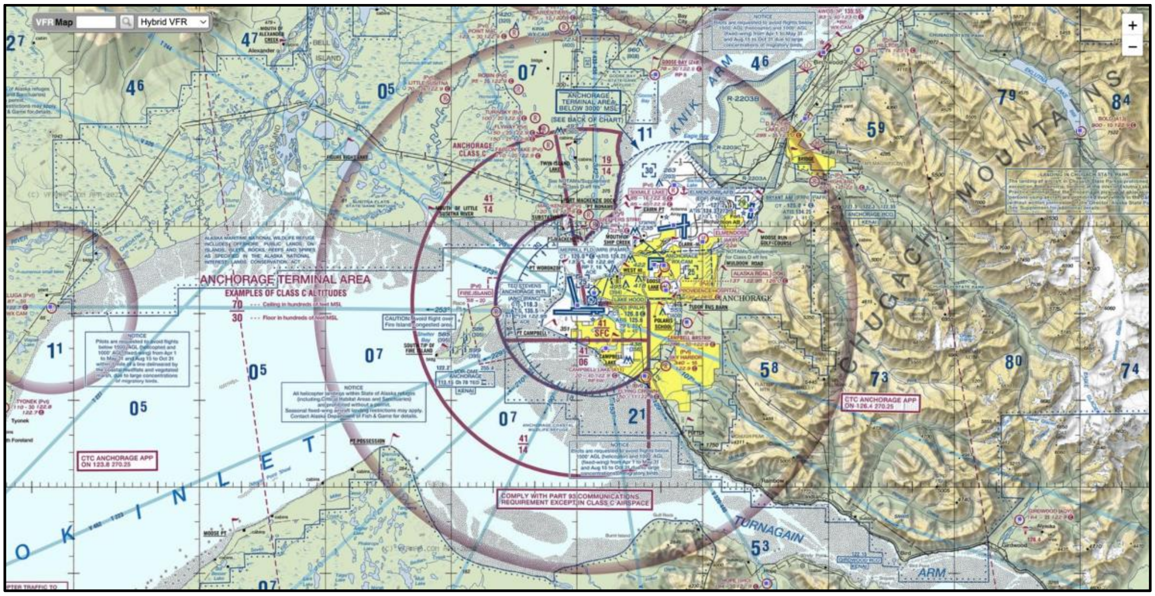
IATA: ANC ICAO: PANC FAA LID: ANC

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

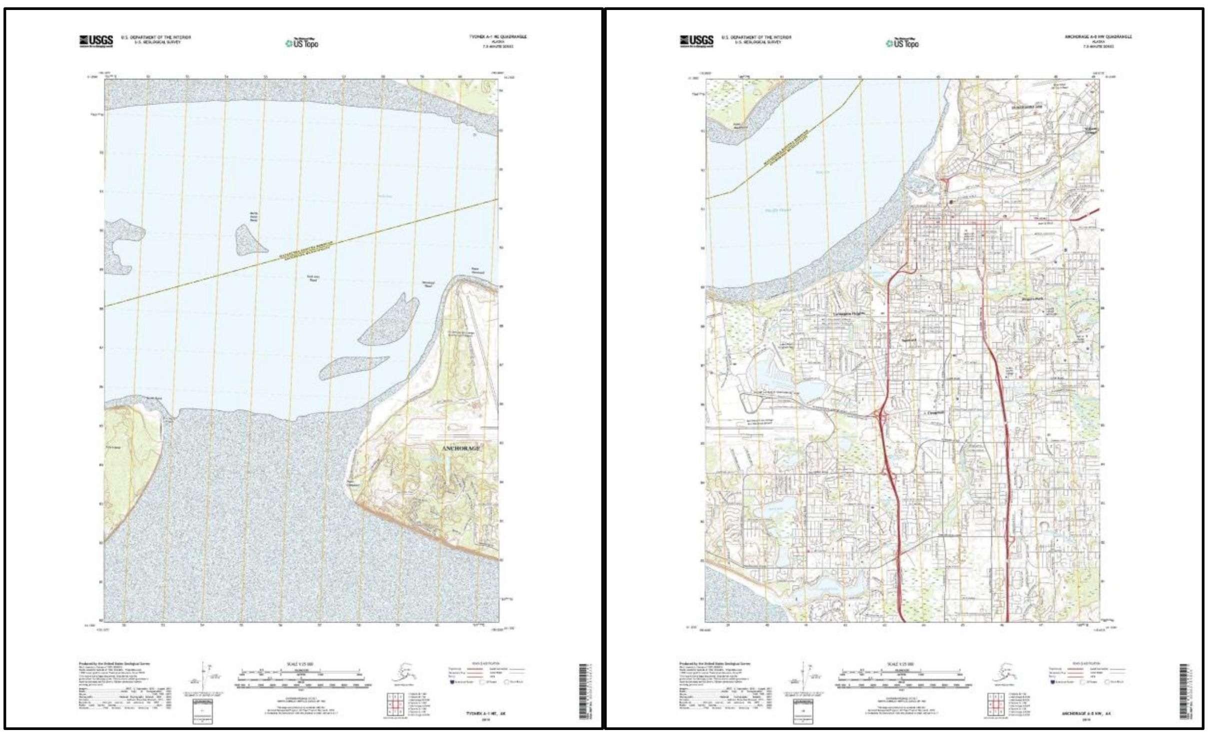
[Anchorage airport map]



[Sectional Charts](#)

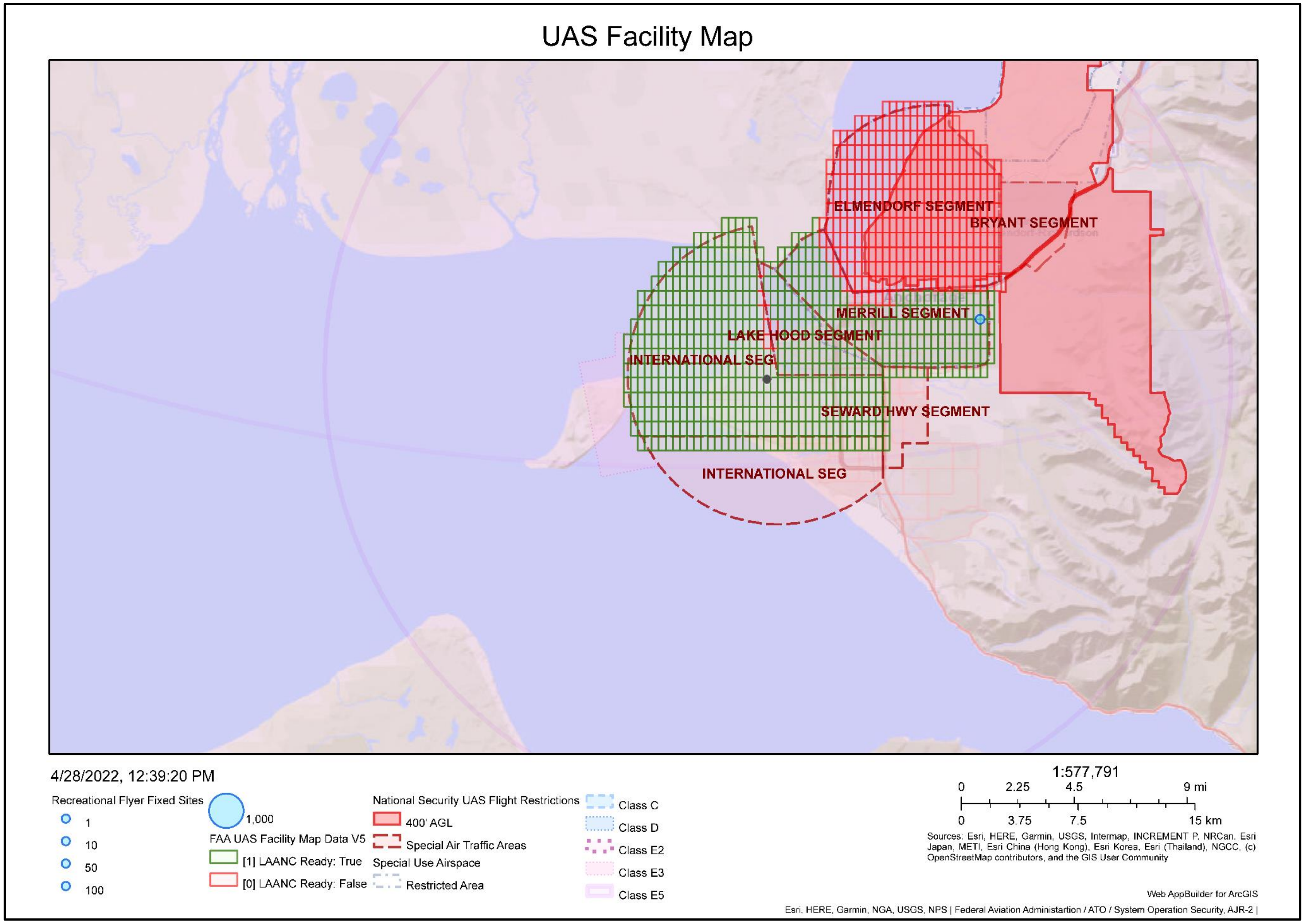


[USGS 7.5-minute topographic map](#)



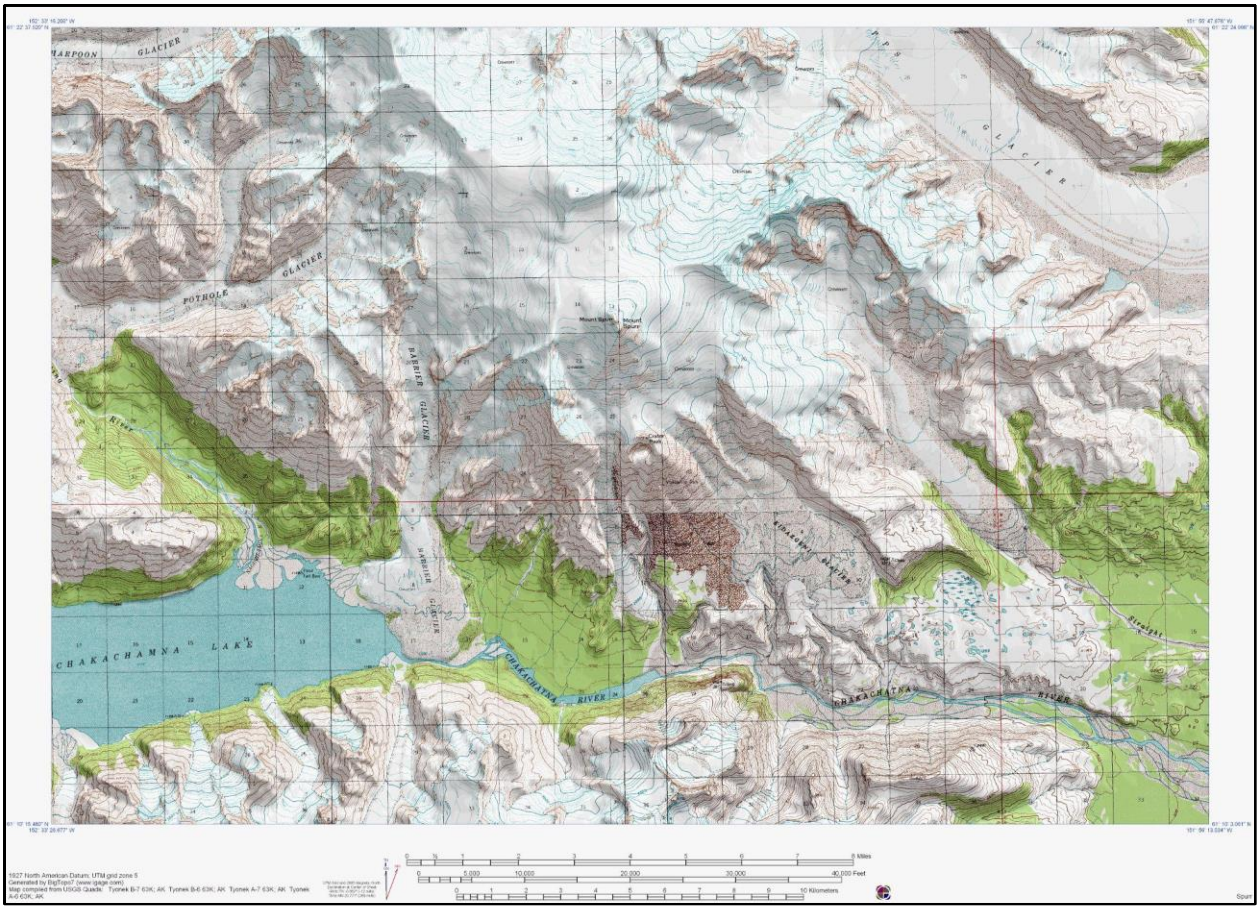
Two maps are required for Anchorage airport and its vicinity.

[Low Altitude Authorization and Notification Capability Facility Maps]



The FAA's Center of Excellence for UAS Research
ASSURE
Alliance for System Safety of UAS through Research Excellence

[Mount Spurr Volcano Summit]



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, Certificate of Authorization Processing
- Page 17 – SGI information: 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 red green blue 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 – Light Detection and Ranging 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)

- Keyhole Markup Zipped (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)
- Meteorological, volcanic ash particulate, and gasses data
  - US-American Standard Code for Information Interchange
  - netCDF4 - Network Common Data Format, (Version 4.x),
  - HDF5 - Hierarchical Data Format (Version 5.x)

Data archiving locations

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