Final Report
ASSURE A28: Disaster Preparedness and Response Using UAS
Attachment 10 – Concept of Operations for Wildland Fires #7

June 1, 2022

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ATTACHMENT 10 - CONCEPT OF OPERATIONS (CONOPS) FOR WILDLAND FIRE #7

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). *The CONOP is to be submitted by the lead organization for the mission.*

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)

Wildland fire detection in spaceborne remote sensing data, need UAS operations to support analysis of its growth and fuels ahead of the spreading fire

Operation:

New wildland fire detected in satellite data. lUAS operations to map landscape and determine where to send sUAS #1 and #2. sUAS #1 operations to map new hotspots seen from satellite. sUAS #2 operations to detect smoke from the new wildland fire. sUAS #3 operations ahead of fire spread to measure VNIR NDVI of fire fuels to support the fire modeling community.

Site: Oregon (Example: Klondike and Taylor Creek from 2018)

Duration of Operation:

At least a day

(It will take time to get lUAS airborne and reach area seen in satellite data, also will need to determine who can support three sUAS missions)

Outcomes/Actionable intelligence:

- Data products support on the ground teams, fire prediction modeling, plume/AQ modeling, and displayed into tools such as NorthWest ICC intelligence and predictive services, and IFTDSS work. Data products at fine scale resolution that provides up to date data like LANDFIRE - https://landfire.gov/fuel.php

- Large UAS (Higher altitude observations) - Adaptable mission to map the full extent of the new fire seen from satellite data. electro-optical (EO) and broadband thermal infrared (TIR) video data feedback to ground control station (GCS) and piped into the operations center to determine where to send small UAS teams. GCS team in communications with operations center and small UAS teams.

- Small UAS #1 (Observations on other missions and backup communications) - provides EO visible and thermal data of all other small UAS missions to assess success to complete missions. Also, onboard communications can support radio connections between small UAS #2 - #4 and the main operations center. These communications will act as mitigation measure to minimize risk that another communications network goes out

- Small UAS #2 (hotspots) - Based on satellite data (Global from NASA), Air boss request, National Oceanic and Atmospheric Administration (NOAA) spot forecast request, local wildland fire alert. Part 107 pilot under visual line of sight (VLOS) goes to locations close to detected fire and fly patterns to collect EO visible and thermal data. Videos feed in real-time back to GCS and piped to decision makers. Imagery taken to build a mosaicked map of visible data with superimposed thermal map. Real-time feed used by event chief to determine need for group ops. Products: Spot Detection and Fire Perimeter map

- Small UAS #3 (plume/cloud content and atmospheric stability/mixing height) - Based on data from small UAS #1, these operations will fly downwind of the fire to measure any smoke particulates and gasses from the fire. Most likely will be flying extend-VLOS (EVLOS) as it will need to fly beyond pilot location to map out the extent of the plume and cloud. Also, it has a sampler onboard to get data back to GCS and displayed in real-time into the GIS tool. Data off the small UAS will be made available to plume models (NOAA-AQ, NOAA-ARL, CONOS HRRR, WRF S-FIRE) and provided to national weather service (NWS) for reporting on airborne particulates and if any significant gas content. Also, it will have onboard atmospheric sensors to provide data to support derivation of mixing height and atmospheric stability of the atmosphere.

- Small UAS #4 (ahead of fire fuels mapping) - This will be set up ahead of the fire locations seen in the satellite data and based on likely fire spread direction. Data will be collected to benefit the fire spread modeling, so will need this input first and define location for operations to provide data to fill a gap in their needs. It will be providing high resolution EO visible, Multispectral data (visible-near infrared, VNIR) with light detection and ranging (LiDAR) of the landscape for fire fuels to support fire spread models (NICC). Real-time: Video feeds of visible data. Fast-turn around: normalized difference vegetation indices (NDVI) and fuel-data from individual images. Post-mission: Mosaicked maps of NDVI and other products such as LiDAR point clouds to assess high resolution maps of vegetation and local canopy.

Metrics of success:

- Large UAS streams data back to the incident center to support assessment of full extent.
- Small UAS #1: Stays airborne throughout, EO & TIR feeds back to GCS, tether continues to support data being streamed back as well as power to prevent need for new batteries
- Small UAS #2 streams back data to support team to assess fire size and provides TIR data to derive fire intensity and map fire perimeter
- Small UAS #3 provides aerosol data to determine constituents of cloud and plume as well as plume top height for the air quality modeling team.
- Small UAS #3 collects atmospheric data (relative humidity [RH], Temperature [T], Pressure [P]) to support derivation of atmosphere stability and mixing ratio
- Small UAS #4 maps the area ahead of the fire and data used to derive 3D models of the landscape from LiDAR with superimposed visible, VNIR, and TIR data.
- Safe flight operations with multiple sUAS operating and data streaming back.
- Both small UAS flew under Part 107 and VLOS is maintained.
- Local Part 107 sUAS pilots respond to requests and data back to the operations center.

1.2 CONOP Quad Chart:

New wildland fire detected in satellite data. lUAS operations to map landscape and determine where to send sUAS #1 and #2. sUAS #1 operations to map new hotspots seen from satellite. sUAS #2 operations to detect smoke from the new wildland fire. sUAS #3 operations ahead of fire spread to measure VNIR NDVI of fire fuels to support the fire modeling community.

1.2.1 Mission Purpose/Objectives

Purpose: Wildland fire seen in satellite data and/or reported from ground teams, need large UAS high altitude operations above, small UAS to keep eyes on all missions and backup communications, small UAS to determine size and intensity, small UAS provide downwind smoke plume and dispersing cloud measurements to support prediction of air quality and other gasses, downwind fire fuels from sUAS to support fire prediction spread modeling.

Goals: Large UAS mapping above the area where fire is seen in satellite data. Small UAS #1 - visible and thermal data to map the fire edge with location defined by detection from satellite feed or other report on fire location. Small UAS #2 - plume [connected to fire] and dispersing cloud sampling downwind of the small UAS #1 operations [also atmospheric data to determine mixing height/determine stability of the atmosphere]. Small UAS #3 - ahead of the fire spread to produce visible-near-infrared (NIR) and thermal infrared (TIR) data to obtain vegetation index information and data to derive fire weather indices at higher resolution from satellite and models. Also, if possible, have LiDAR to map local vegetation and provide data on any canopy to help fire spread modeling determine if surface fire could jump to canopy fire. Get multiple small UAS in the air to provide essential data to better understand the fire size and fill data gaps to support the team to predict the air quality/cloud dispersal and fire spread. Show how small UAS can together provide an improved understanding of a fire and provide the data that modeling groups need to better predict airborne and ground hazards.

Objectives: Large UAS provides a higher altitude view of the event and support teams to determine positions for the small UAS. Small UAS #1 is a tethered system at a fixed location to support teams to get real-time analysis of missions as they are ongoing and to support teams to evaluate effectiveness of missions and the implementation of the operational missions. Small UAS #2 provides thermal and visible-NIR data to map out the fire perimeter and provide broadband thermal infrared data to derived ground temperatures. Small UAS #3 provide aerosol and gas observations to map the plume and downwind cloud as well as atmospheric measurements to support air quality assessment team to derive atmospheric stability and mixing ratio. Small UAS #4 provides visible-NIR, TIR, and LiDAR data to map the downwind fire fuels to support the fire spread modeling team and fill data gaps. Evaluate how small UAS missions can respond to other small UAS operations and data analysis. Evaluate how 107 pilots can respond to operational needs where the launch site depends on fire location and downwind direction and how a suite of Part 107 operations can provide full aspects of wildland fire current size and likelihood to spread.

1.2.2 Mission Procedures/Approach

Large UAS: Eyes above and support sUAS position

Take-off from nearby airport once report of fire. Site 1 in Oregon - Eugene if responding to Klondike/Taylor Creek '18 fire; Site 2 in Alaska - Anchorage if responding to Funny River '14 fire; Site 3 in New Mexico - Santa Fe if responding to El Rito '21 fire

Beyond line of sight (BVLOS) operations; Flown from runway to traverse to fire location

Route defined to reach site efficiently and then holding pattern to keep eyes on fire

Day of flying to reach site and provide high altitude eyes on disaster

Small UAS #1: Tethered to watch other small UAS and communication link if needed

Stays airborne to watch all following missions; Take-off location dependent on fire location and any updates from large UAS data

Part 107 and visual line of sight (VLOS) operations; Fly VLOS or extended-VLOS under visual flight rules (VFR) conditions

This will act as fixed tethered view of all of the missions

Electro-optical visible and thermal data shared through tethered system; Sensor field of view allows full view of all operations [take-off, flight, and landings]

Small UAS #2: Mapping of the fire to determine intensity and perimeter

Take-off location selected to support analysis of the fire size

Part 107 and VLOS operations; Electro-optical visible, NIR, and TIR camera suite

Provide real-time data and build mosaiced maps and three-dimensional models

Route defined to cover the fire and map is thermal signal and edge

Small UAS #3: Plume/Cloud details and atmospheric conditions

Take-off location selected based on location of the fire and plume; Mission design to measure plume top height and then direction and dimensions of cloud

Part 107 and may require EVLOS operations; Maybe instrument flight rules (IFR) conditions if the plume/cloud optically thick

Aerosol sampler, gasses sensor, with include relative humidity (RH), temperature (T), and Pressure

Real-time data to provide where plume top is detected; Sample the plume and follow dispersing cloud, manual flight based on the data at ground control station

Small UAS #4: Fire fuels and landscape details ahead of fire spread and upwind of plume/cloud

Take-off location selected based on fire location and need for data where fire will spread

Gridded data collected to map the landscape ahead of the fire

Part 107 but might require EVLOS given distance to cover based on pilot in command location

Electro-optical visible, NIR, and TIR camera suite along with LiDAR, if possible, to measure height of vegetation and any canopy

Real-time electro-optical visible data streamed back so that manual flight can be selected if needed

Fire spread modeling team member with PIC to assess the areas that needs mapping

Maybe IFR conditions if the plume/cloud optically thick over the area to be mapped

1.2.3 Mission Results

Observations: Recording of full extent of the fire as it progresses. lUAS data feeds back to EM Ops Center and to support sUAS teams to produce fine-scale data needed by ground team, AQ modelers and fire spread modeling team. sUAS #1 to support eyes on the event and communications hub if needed. sUAS #2 to map fire perimeter and intensity, sUAS #3 to measure plume height plus composition as well as atmospheric conditions, sUAS #4 to map fire fuels ahead of the fire spread and fill data gaps needed by the modeling team.

Real-time mission Products: lUAS provides RGB and TIR feeds to support ground teams on where to place sUAS. sUAS #1 is flown from set-location, that can move to location as defined needs arise, to support teams to get real-time analysis of missions as they are ongoing and to support teams to evaluate effectiveness of missions and the implementation of the CONOPS. sUAS #2 provides RGB-NIR/TIR data in real-time and observations to determine fire perimeter and intensity. sUAS #3 provides vertical profiles of plume/cloud top height and RH, T, and P to derive plume/cloud composition along with atmosphere stability and mixing height. sUAS #4 provides real-time feed of RGB-NIR and TIR data.

Post-Mission [fast response] Products: lUAS: Geospatial located video feeds to show field of view to analyze full extent of fire. sUAS#1: Full FOV of the missions with geo- and time-tagged data to compare to data from other sUAS and flight software. sUAS #2: Derived ground surface temperature of fire and perimeter. Mosaiced maps with derived properties of landscape along with DEM/DSM/3D models where SfM is possible. sUAS #3: Plume/cloud composition along sUAS route including vertical and horizontal profiles. Atmospheric data used to derive atmospheric stability and allow the AQ modeling team to measure mixing ratio. sUAS #4: LiDAR 3D point clouds of the upwind landscape and infrastructure ahead of the fire and where it is predicted to spread. Mosaiced maps with derived properties of landscape along with DEM/DSM/3D models where SfM is possible. Superimposed TIR and NIR/NDVI data on 3D models from RGB and LiDAR data.

1.2.4 Mission Milestones

Outcomes/Actionable Intelligence

Large UAS [Higher altitude eyes] - Adaptable mission to map the full extent of the new fire seen from satellite data. Electro-optical visible and thermal infrared video data feedback to ground control station (GCS) and piped into operations center to determine where to send small UAS teams. GCS team in communications with operations center and small UAS teams.

Small UAS #1 [Eyes on missions and backup communications] - provides electro-optical visible and thermal data of all other small UAS missions to assess success to complete missions. Onboard communications can support radio connections between small UAS #2 - #4 and main operations center. These communications will act as mitigation measure to minimize risk that another communications network goes out

Small UAS #2 [hotspots] - Based on satellite data with accompanying spot weather forecast request, and local wildland fire alert. Part 107 pilot under VLOS goes to locations close to detected fire and fly patterns to collect electro-optical visible and thermal data. Videos feed in real-time back to GCS and piped to decision makers. Imagery taken to build a mosaicked map of visible data with superimposed thermal map. Real-time feed used by event chief to determine need for group ops. Products: Spot Detection and Fire Perimeter map

Small UAS #3 [plume/cloud content and atmospheric stability/mixing height] - Based on data from small UAS #1, these operations will fly downwind of the fire to measure any smoke particulates and gasses from the fire. Most likely will be flying EVLOS as it will need to fly beyond pilot location to map out the extent of the plume and cloud. It will gave a sampler onboard to get data back to GCS and displayed in real-time into the visualization tool. Data off the small UAS available to plume model community and provided to U.S. National Weather Service (NWS) for reporting on airborne particulates and if any significant gas content. It will have onboard atmospheric sensors to provide data to support derivation of mixing height and atmospheric stability of the atmosphere.

Small UAS #4 [ahead of fire fuels mapping] - This will be set up ahead of the fire locations seen in the satellite data and based on likely fire spread direction. Data will be collected to benefit the fire spread modeling, so will need this input first and define location for operations to provide data to fill a gap in their needs. It will be providing high resolution visible, multispectral data [visible+Red-edge+near-infrared] with where possible LiDAR of the landscape for fire fuels to support fire spread models. Real-time: Video feeds of electro-optical visible data. Fast-turn around: Vegetation indices and fuel-data from individual images. Post-mission: Mosaicked maps of vegetation indices and other products such as point clouds to assess high resolution maps of vegetation and local canopy.

Metrics of success

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

Small UAS #1: Stays airborne, electro-optical visible and thermal infrared feeds back to GCS, tether continues to support data being streamed back and power to prevent need for new batteries

Small UAS #2 streams back data to support team to assess fire size and provides TIR data to derive fire intensity and map fire perimeter

Small UAS #3 provides aerosol data to determine constituents of cloud and plume as well as plume top height for air quality modeling team.

Small UAS #3 collects atmospheric data to support derivation of atmosphere stability and mixing ratio

Small UAS #4 maps the area ahead of the fire and data used to derive three-dimensional models of the landscape with superimposed visible, NIR, and TIR data.

Safe flight operations with multiple small UAS operating and data streaming back.

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

1.3 Situation

1.3.1 Overview

Purpose: Wildland fire seen in satellite data and/or reported from ground teams, need large UAS high altitude operations above, small UAS to keep eyes on all missions and backup communications, small UAS to determine size and intensity, small UAS provide downwind smoke plume and dispersing cloud measurements to support prediction of AQ and other gasses, downwind fire fuels from sUAS to support fire prediction spread modeling.

Goals of the mission: Large UAS mapping above the area where fire is seen in satellite data. Small UAS #1 - tethered system with visible and thermal sensor to monitor the success of UAS missions #2 - #4. Small UAS #2 - visible and thermal observations to map the fire edge with location defined by detection from satellite feed or other report on fire location. Small UAS #2 - plume (connected to fire) and dispersing cloud sampling downwind of the small UAS #1 operations (also atmospheric data to determine mixing height/determine stability of the atmosphere). Small UAS #4 - ahead of the fire spread to produce VNIR and TIR data to obtain NDVI and data to derive fire weather indices at higher resolution from satellite and models. Will also have LiDAR to map local vegetation and provide data on any canopy to help fire spread modeling determine if surface fire could jump to canopy fire

UAS mission Lead: ACUASI team as UAS operations along with state Emergency Operations Center; Teams at local operations site.

Overall:
US Forest Service, Air boss at incident command. Communicate with flight leads

Large UAS: High altitude observations of the event

- Flight team lead with crew
- Flight in and out of nearby airport - Tillamook Range

Small UAS #1: Visible and thermal to support evaluation on success of small UAS #2 to #4

- Pilot in command (PIC) and visual observer (VO)
- Electro-optical visible and thermal sensors

<u>Small UAS #2</u>: Visible and thermal mapping of the fire location

- Pilot in command (PIC) and visual observer (VO)
- Electro-optical visible and thermal sensors

<u>Small UAS #3</u>: Sampling the ashes from the wildland fire

- Pilot in command (PIC) and visual observer (VO)
- Electro-optical visible and thermal sensors
- Site chosen based on predictions of wildland ash cloud dispersal
- Vertical profile data collection rather than regional mapping

<u>Small UAS #4</u>: Mapping of the fire fuels ahead of the fire

- Pilot in command (PIC) and visual observer (VO)
- Electro-optical visible and thermal sensors
- VNIR and TIR ahead of spread of fire to provide data to derive NDVI and fire fuel indices to support modeling and assessment of fire spread
- Added LiDAR to support local vegetation mapping and assessment of any canopy

1.3.2 Location

Large UAS: Tillamook Airport, Oregon

Latitude: 45.4182500ºN Longitude: 123.8143889ºW

IATA: OTK ICAO: KTMK FAA LID: TMK

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

Small UAS: Klondike/Taylor Creek, Oregon

Latitude: 42.3962206ºN Longitude: 123.901746ºW

All Maps in Appendix 3

1.3.3 Systems

<u>Central Operations</u>

- Coordination with all flight teams
- Based at local operations center
- Large UAS operators: for example, ACUASI Director of Operations Adkins to support data stream into operations center
- USFS/USDA, Air Boss, FAA, and FEMA representatives

<u>1st flight - will take time to respond, provide large scale mapping of extent</u>

- Large UAS
    - SeaHunter/Sentry type from local airport: Tillamook
    - 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
        - Electro-optical feed is sent back to ground control station (GCS) and onto operations center
        - Optical and thermal payload integrated for nadir viewing
    - Optical feed is sent back to GCS and onto operations center
    - Arrives at site with holding pattern to keep observations on it
    - Manual operations so flight route adapted based on fire spread needs
    - Airborne throughout, nadir feed of thermal data supports team to determine where to send the small UAS for fire analysis, downwind plumes, and fire fuels ahead of spread.

2nd flight up to provide small UAS observations on all missions

- Small UAS #1
    - VTOL system on a tether
    - Continuous operations throughout all missions
    - Endurance of an hour per flight that can be quickly sent back up
    - Launch location based on where fire is based and observations from large UAS
    - Flight team
        - Part 107 Pilot in Command (PIC) + visual observer (VO)
        - Engineering support [if possible as VO]
    - Minimum Payload
        - Electro-optical with thermal: Pointable with fixed nadir option
    - Provides data to analyze effectiveness of all missions
    - FOV can see all operations including all take-off and landing of other small UAS
    - Data fed back to GCS and onto Ops Center

3rd flights up: Map out fire perimeter and intensity under EO/VNIR with thermal option

- Small UAS #2
    - VTOL and up to 45 minutes endurance per flight
    - Launch location based on where fire is based and observations from large UAS
    - Flight team
        - Part 107 Pilot in Command (PIC) + visual observer (VO)

        - Engineering support [if possible as VO]
    - Minimum Payload
        - Electro-optical with VNIR and thermal: Pointable with fixed nadir option
        - Detect fire and analyze its spread
    - Data feedback to GCS and onto Ops Center
    - Routine pattern to map the fire
    - Adapt with manual operations to follow fire as progress
    - Real-time video of the fire as it burns

4th flights up: Measure aerosols and gasses in plume and cloud + atmospheric conditions

- Small UAS #3
    - VTOL to support vertical profiles
    - Downwind of fire seen in small UAS #2 and large UAS data operations
    - Site chosen based on predicted cloud locations
    - VLOS with Part 107 waiver if needed based on time of day/location/altitude
    - VFR conditions
    - Flight team
        - Part 107 Pilot in Command (PIC) + visual observer (VO)
        - Engineering support [if possible as VO]
    - Minimum Payload
        - Electro-optical 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
    - Real-time data: Plume and dispersing cloud top height and RH, Press, Temperature with altitude
    - Post-flight data: Resolved aerosol particulates and gas concentrations, atmospheric stability, and mixing ratio

5th flight up Ahead of fire spread fire fuels and vegetation mapped via LiDAR

- Small UAS #4
    - VTOL system
    - Downwind of fire in location predicted by fire spread modeling
    - Site chosen to collect critical data on landscape to assess likely fire growth
    - VLOS with Part 107 waiver if needed based on time of day/location/altitude
    - VFR conditions
    - Flight team
        - Part 107 Pilot in Command (PIC) + visual observer (VO)
        - Engineering support [if possible as VO]
    - Minimum Payload
        - Electro-optical, VNIR, with thermal: Pointable with fixed nadir option

        - If possible, LiDAR to support derivation of point clouds of landscape to assess if fire moving towards canopy
    - Fly defined route pattern to map area burned
        - Adaptive route depending on change in fire spread based on modeling updates

1.4 Mission

Disaster:

Wildland fire is detected by either satellite data or other observations and needs assessment of fire intensity and perimeter along with information on aerosols/gasses from plume and dispersing cloud. AQ modeling team needs data on plume height and atmospheric stability while a fire spread modeling team needs data on fire fuels and infrastructure ahead of fire. Site 1 (OR): equivalent to Klondike/Taylor Creek ‘18 fire.

Observations

Recording of the full extent of the fire as it progresses. Large UAS data feeds back to the operations center and to support small UAS teams to produce fine-scale data needed by ground team, air quality modelers and fire spread modeling team. Small UAS #1 to support eyes on the event and communications hub if needed. Small UAS #2 to map fire perimeter and intensity. Small UAS #3 to measure plume height plus composition as well as atmospheric conditions. Small UAS #4 to map fire fuels ahead of the fire spread and fill data gaps needed by the modeling team.

Response mission:

Fire detected from satellite or ground. Need rapid response to assess fire size and intensity, plume/cloud composition, atmospheric conditions, and fuels ahead of the fire as it spreads. Data to support ground team to assess fire size, support air quality modeling team on plume/cloud details and fire spread team on filling data gaps on fire fuels.

Stakeholders:

United States Forest Service on managing the fire. Local operations and ground team on where to send assets. National Oceanic and Atmospheric Administration (NOAA) on input data for the air quality modeling. United States Department of Agriculture on their fire spread modeling team. Local Division of Natural Resources and any communities upwind of the fire.

Goals:

Get multiple small UAS in the air to provide essential data to better understand the fire size and fill data gaps to support the team to predict the air quality/cloud dispersal and fire spread. Show how small UAS can together provide an improved understanding of a fire and provide the data that modeling groups need to better predict airborne and ground hazards.

Objectives:

Large UAS provides a higher altitude view of the event and support teams to determine positions for the small UAS. Small UAS #1 is a tethered system at a fixed location to support teams to get real-time analysis of missions as they are ongoing and to support teams to evaluate effectiveness of missions and the implementation of the CONOPS. Small UAS #2 provides thermal and VNIR data to map out the fire perimeter and provide broadband TIR data to derived ground temperatures. Small UAS #3 provide aerosol and gas observations to map the plume and downwind cloud as well as atmospheric measurements to support the air quality team to derive atmospheric stability and mixing ratio. Small UAS #4 provides VNIR, TIR, and LiDAR data to map the downwind fire fuels to support the fire spread modeling team and fill data gaps. Evaluate how small UAS missions can respond to other small UAS operations and data analysis. Evaluate how 107 pilots can respond to operational needs where the launch site depends on fire location and downwind direction and how a suite of Part 107 operations can provide full aspects of wildland fire current size and likelihood to spread.

Mission Products

- Large UAS provides EO visible and TIR feeds to support ground teams on where to place small UAS
- Small UAS #1 is flown from set-location, that can move to location as defined needs arise, to support teams to get real-time analysis of missions as they are ongoing and to support teams to evaluate effectiveness of missions and the implementation of the CONOPS
- Small UAS #2 provides VNIR/TIR data in real-time and observations to determine fire perimeter and intensity
- Small UAS #3 provides vertical profiles of plume/cloud top height and RH, T, and P to derive plume/cloud composition along with atmosphere stability and mixing height.
- Small UAS #4 provides real-time feed of VNIR and TIR data.

Post-Mission (fast response) Products:

- Large UAS: Geospatial located video feeds to show field of view to analyze full extent of fire.
- Small UAS #1: Full FOV of the missions with geo- and time-tagged data to compare to data from other small UAS and flight software.
- Small UAS #2: Derived ground surface temperature of fire and perimeter. Mosaiced maps with derived properties of landscape along with DEM/3D models where SfM is possible.
- Small UAS #3: Plume/cloud composition along a small UAS route including vertical and horizontal profiles. Atmospheric data used to derive atmospheric stability and allow the air quality modeling team to measure mixing ratio.
- Small UAS #4: LiDAR 3D point clouds of the upwind landscape and infrastructure ahead of the fire and where it is predicted to spread. Mosaiced maps with derived properties of landscape along with DEM/3D models where SfM is possible. Superimposed TIR and NIR/NDVI data on 3D models from visible and LiDAR data.

1.5 Execution

1.5.1 Operations Plan

Large UAS

High altitude data above and support sUAS position

- Site 1: equivalent to Klondike/Taylor Creek ‘18 fire
- Take-off from nearby airport once report of fire that needs analysis
- Operations from Tillamook as if responding to Klondike/Taylor Creek ‘18 fire
- BVLOS operations
- Flown from runway to traverse to fire location
- Route defined to reach site efficiently and then holding pattern to keep eyes on fire
- Day of flying to reach site and provide high altitude eyes on disaster
- VFR/IFR conditions as will be BVLOS
- Follow pre-flight, during, and post-flight checklist for large UAS like SeaHunter/Sentry

<u>Small UAS #1</u>

Tethered to watch other sUAS and communication link if needed

- Take-off location dependent on fire location and any updates from large UAS data
- Part 107 and VLOS operations
- This will act as fixed tethered view of all the missions
- EO and TIR data shared through tethered system
- Field of View allows full view of all operations (take-off, flight, and landings)
- Fly VLOS or EVLOS under VFR conditions
- Follow pre-flight, during, and post-flight checklist for small UAS, need for VO per aircraft

<u>Small UAS #2</u>

Mapping of the fire to determine intensity and perimeter

- Take-off location selected to support analysis of the fire size
- Part 107 and VLOS operations
- EO/VNIR/TIR camera suite
- Provide real-time data and build mosaiced maps and 3D models
- Route defined to cover the fire and map is thermal signal and edge
- VFR conditions as will be VLOS
- Follow pre-flight, during, and post-flight checklist for small UAS

<u>Small UAS #3</u>

Plume/Cloud details and atmospheric conditions

- Take-off location selected based on location of the fire and plume
- Mission design to measure plume top height and then direction and dimensions of cloud
- Part 107 and may require EVLOS operations
- Aerosol sampler, gasses sensor, with include RH, T, and Pressure
- Real-time data to provide where plume top is detected
- Sample the plume and follow dispersing cloud, manual flight based on the data at GCS
- Maybe IFR conditions if the plume/cloud optically thick
- Follow pre-flight, during, and post-flight checklist for small UAS

<u>Small UAS #4</u>

Fire fuels and landscape details ahead of fire spread and upwind of plume/cloud

- Take-off location selected based on fire location and need for data where fire will spread
- Gridded data collected to map the landscape ahead of the fire
- Part 107 but might require EVLOS given distance to cover based on PIC location
- EO/VNIR/TIR camera along with LiDAR to measure height of vegetation and any canopy
- Real-time EO data streamed back so that manual flight can be selected if needed
- Fire Spread modeling team member with PIC to assess the areas that needs mapping
- IFR conditions if the plume/cloud optically thick over the area to be mapped
- Follow pre-flight, during, and post-flight checklist for small UAS

1.5.2 Data collection, processing, and dissemination

Large UAS

Full extent of disaster above the fire location and dispersing plume/cloud

- Data in flight:
    - High Precision locations and time synchronization of flight
    - Flight routes and logs from crew
    - Geotagged optical and thermal infrared data of Anchorage, Palmer, and Seward
    - Decimeter res. visible data from high definition (HD) multi-megapixel camera
    - Broadband thermal infrared [7 - 13 μm] data: Minimum 640 x 480 resolution
    - 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

Small UAS #1

Tethered sUAS to watch over other small UAS missions and provide communications if needed

- Data in flight:
    - High Precision locations and time synchronization of flight
    - Flight routes and logs from crew
    - Geotagged optical and thermal infrared video imagery of all missions
    - Time-tagged data to cross-compare with all other operations
    - Optical and thermal data streamed to PIC, GCS, and operations center
    - 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

Small UAS #2

Mapping of the fire to determine intensity and perimeter

- Data in flight:
    - High Precision locations and time synchronization of flight
    - Flight routes and logs from crew
    - Geotagged optical and thermal infrared data
    - Decimeter res. visible data from high definition (HD) multi-megapixel camera
    - Broadband thermal infrared [7 - 13 μm] data: Minimum 640 x 480 resolution
    - 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
    - Derived ground surface temperature and geospatial data on fire edge

<u>Small UAS #3</u>

Plume/Cloud details and atmospheric conditions

- 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
    - 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 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 concentrations along flight routes
    - Three-dimensional profiles of atmospheric parameters along flight routes
    - Derived data on atmospheric stability and mixing ratio

<u>Small UAS #4</u>

Fire fuels and landscape details ahead of fire spread and upwind of plume/cloud

- Data in flight:
    - High Precision locations and time synchronization of flight
    - Flight routes and logs from crew
    - Geotagged optical, VNIR, thermal infrared imagery of landscape
    - If available, Geotagged 3D point clouds from LiDAR sensor
    - Decimeter res. visible data from high definition (HD) multi-megapixel camera
    - Broadband thermal infrared [7 - 13 μm] data: Minimum 640 x 480 resolution
    - 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
    - Orthomosaic of visible and thermal brightness temperature
    - Derived ground surface temperature of the landscape ahead of fire
    - Orthomosaic of EO data along with NDVI and fire potential of the landscape
    - 3D point clouds from the LiDAR data with superimposed visible data

1.6 Administration & Logistics

1.6.1 Planning and local logistics

Large UAS team will have accommodation at a hotel nearby to 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 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 National Airspace System (NAS) to the terrorism event. If Temporary Flight Restriction (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.

Small UAS #1 will be tethered to provide a fixed location for operations. Small UAS pilots in command and UAS missions lead will liaise with the emergency operations center to define allowed locations for tethered UAS. 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. All small UAS flight crews will need access to the site of the wildland fire through local ground crew vehicles and require overnight accommodation.

1.6.2 Hazards/Risk

<u>Hazard #1</u>: Toxic ash and gases

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

Hazard #2: Severe Weather Conditions

- Risk: This hazard is a result of atmospheric conditions that change so there is a no-go for flight operations. Possible effects are a stop in flight operations and an aircraft that must rapidly RTL or end flight and the team left waiting and unable to complete their mission.
- Mitigation: During flight, if weather conditions deteriorate suddenly, the PIC assesses if DLI is required or if they can invoke RTB resulting in a suspension of the onward flight path. DLI will ensure that the flight lands safely as close as possible to the original location. If the PIC can determine that flight can still operate with the RTB in place, then the UAS will follow this pattern, i.e., its launch/landing point. If this is not possible given the weather conditions, the mission will use the defined landing zones developed in the CONOP to divert land immediately. If there are multiple UAS flights at the same time and in the same airspace supporting a disaster response, then pre-mission coordination on each flight's alternative landing zones will occur to mitigate any mid-air collisions from DLI or RTB flights.

Hazard #3: Ash/gas clouds move away from flight route

- Risk: This hazard is a result of the downwind clouds that need to be measured moving and dispersed away or towards the small UAS and away from the pre-defined flight route. Possible effects are a flight route that cannot provide observations or runs out of power or would need to fly under VLOS before collecting all the data.
- Mitigation: During this flight, the PIC will ensure that the UAS can capture the data needed for the disaster response and could be flying a defined flight path. The PIC will work with their flight crew to be informed on the future plume and cloud dispersal so that they can be prepared to manually fly the aircraft to locations where the observations needed can be collected. If this requires VLOS operations, the crew will review if the permissions are in place to support this type of mission before proceeding.

Hazard #4: 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 #5: 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 observations. 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 observations 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 #6: Crew unable to provide visual observations for small UAS flight

- Risk: This hazard comes from a required flight time of the small UAS missions extending beyond the visual observation capabilities of the crew 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 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 #7: Loss of communications between multiple UAS flight crews

- Risk: This hazard comes from multiple small UAS flying at the same time in proximity and a lack of communications between each flight crew. Possible effects are a crash of the small UAS as flight routes cross, a near miss as some flight routes are manual while others are automated, or a RTB or rapid descent of a UAS to prevent a crash or near miss and continue safe operations for all UAS.
- Mitigation: Before the mission, each PIC will check their communications between their flight location and the centralized mission team and with the other PICs and their flight crew. The different UAS flight teams will ensure that each is aware of the communication frequencies to use and the call signs and terms that each team will be using. Each flight team will be able to see the location of the other UAS in their flight management software and if needed can communicate through the centralized mission team. One flight team member will be able to communicate with the other teams and will not take on the PIC or VO role for the flight. Each team will have backups in case their communications drop with the operational radio and if

these fail, they will perform a DLI or RTB that will demonstrate to the other teams that their communications are broken and cannot perform safe operations.

Hazard #8: Loss of power and data transfer to tethered UAS

- Risk: This hazard comes from a lack of continued power and data transfer across the UAS tether. Possible effects are that the tethered UAS must descend to obtain new batteries as power and mission loses the capabilities that the UAS provides.
- Mitigation: Before the mission starts, the PIC for the tethered UAS will perform safety checks for the tethering system and check that power and data can be received by the aircraft and data sent back to the ground station. If there is a drop in power and data transfer, the PIC and their flight team will monitor the issue. Once it reaches close to their safety limits, the aircraft will descend with sufficient power to ensure a safe landing. All data collected will be removed from the onboard sensors and the power issue evaluated. If possible, the aircraft will return to its tethered altitude to provide the support needed.

Hazard #9: Tether breaks on the small UAS

- Risk: This hazard comes from a broken tether between the ground station and the airborne platform. Possible effects are a free flying UAS, that should be tethered to the ground, and does not have a pre-defined flight route and therefore is in fly-away mode.
- Mitigation: The PIC for the mission will take over manual control of the aircraft and either perform a DLI or RTB for the aircraft. The flight crew will use a small UAS that can be both a tethered UAS with data transfer and power provided by the tethered as well as a mobile UAS that can be manually controlled by the flight PIC. The flight crew will have a VO that can act if the aircraft does fly away from its tether and will communicate with the PIC.

1.6.3 Community outreach and connections

All Operations: Tillamook community and airport through incident command team or a statewide operations center if one that has been setup. USFS for information on the wildland fire location.

Small UAS: Three missions. Coordination between flight teams on who will fly each mission. Also, will need to coordinate with ground teams as well as USFS on access to site locations for launch of UAS to support operations.

1.6.4 Disaster response mission specific information

- ArcGIS Story Map of the 2018 Wildland fire - National Interagency Fire Center. (n.d.). *Unmanned Aircraft Systems for Wildland*
- Oregon Emergency Response System (OERS) that coordinates and manages state resources in response to natural and technological emergencies and civil unrest involving multi-jurisdictional cooperation between all levels of government and the private sector.
- Spot forecast for fire location region from National Weather Service (NWS). This is downloaded to the flight checklist documentation for each crew and GCS.
- Wildland fire conditions provided by Northwest Interagency Coordination Center (NIFC)

1.6.5 Mission Summary

Disaster:

Wildland fire is detected by satellite data and ground observations and needs assessment of fire intensity and perimeter along with information on aerosols/gasses from plume and dispersing cloud. Air quality modeling team needs data on plume height and atmospheric stability while the fire spread modeling team needs data on fire fuels and infrastructure ahead of fire.

Observations

Recording of the full extent of the fire as it progresses. Large UAS data feeds back to the operations center and to support small UAS teams to produce fine-scale data needed by ground team, air quality modelers and fire spread modeling team. Small UAS #1 to support eyes on the event and communications hub if needed. Small UAS #2 to map fire perimeter and intensity. Small UAS #3 to measure plume height plus composition as well as atmospheric conditions. Small UAS #4 to map fire fuels ahead of the fire spread and fill data gaps needed by the modeling team.

Flight Missions:

Large UAS is flown to provide an overview of the disaster. Small UAS #1: Tethered mission that is airborne before any other operations start. Small UAS #1 will stay airborne throughout all others and support evaluation of the effectiveness of the other missions. Small UAS #2 used to measure fire size and intensity. Data provided to ground teams through operations center and air quality/fire modeling teams. Small UAS #3 used to record data on the fire plume and dispersing cloud as well as data to determine atmospheric stability and mixing ratio. Data from small UAS #3 provided to the air quality modeling team. Small UAS #4 to map the landscape ahead of the fire to determine information on fire fuels including details on vegetation cover and if any nearby canopy. Data provided to the fire spread assessment team and operations center to help assess what the fire might do.

Metrics of success:

- Large UAS streams data back to the incident center to support assessment of full extent.
- Small UAS #1: Stays airborne throughout, EO & TIR feeds back to GCS, tether continues to support data being streamed back as well as power to prevent need for new batteries
- Small UAS #2 streams back data to support team to assess fire size and provides TIR data to derive fire intensity and map fire perimeter
- Small UAS #3 provides aerosol data to determine constituents of cloud and plume as well as plume top height for the air quality modeling team.
- Small UAS #3 collects atmospheric data (relative humidity [RH], Temperature [T], Pressure [P]) to support derivation of atmosphere stability and mixing ratio
- Small UAS #4 maps the area ahead of the fire and data used to derive 3D models of the landscape from LiDAR with superimposed visible, VNIR, and TIR data.
- Safe flight operations with multiple sUAS operating and data streaming back.
- Both small UAS flew under Part 107 and VLOS is maintained.

- Local Part 107 sUAS pilots respond to requests and data back to the operations center.

1.7 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.

1.8 Supplementary appendices to accompany CONOP

1.8.1 Appendix 1: Operational Details – One Pager

Mission and Disaster Preparedness/Response

New wildland fire detected in satellite data. lUAS operations to map landscape and determine where to send sUAS #1 and #2. sUAS #1 operations to map new hotspots seen from satellite. sUAS #2 operations to detect smoke from the new wildland fire. sUAS #3 operations ahead of fire spread to measure VNIR NDVI of fire fuels to support the fire modeling community.

Site 1: Oregon [Example: Klondike and Taylor Creek from 2018]
Site 2: New Mexico [Example: Pose Fire, El Rito, NM - from 2021]
Site 3: Alaska [Example: Funny River from 2014]

Mission Purpose/Objectives

Purpose : Purpose: Wildland fire seen in satellite data and/or reported from ground teams, need large UAS high altitude operations above, small UAS to keep eyes on all missions and backup communications, small UAS to determine size and intensity, small UAS provide downwind smoke plume and dispersing cloud measurements to support prediction of air quality and other gasses, downwind fire fuels from sUAS to support fire prediction spread modeling.

Goals : Large UAS mapping above the area where fire is seen in satellite data. Small UAS #1 - visible and thermal data to map the fire edge with location defined by detection from satellite feed or other report on fire location. Small UAS #2 - plume [connected to fire] and dispersing cloud sampling downwind of the small UAS #1 operations [also atmospheric data to determine mixing height/determine stability of the atmosphere]. Small UAS #3 - ahead of the fire spread to produce visible-near-infrared (NIR) and thermal infrared (TIR) data to obtain vegetation index information and data to derive fire weather indices at higher resolution from satellite and models. Also, if possible, have LiDAR to map local vegetation and provide data on any canopy to help fire spread modeling determine if surface fire could jump to canopy fire. Get multiple small UAS in the air to provide essential data to better understand the fire size and fill data gaps to support the team to predict the air quality/cloud dispersal and fire spread. Show how small UAS can together provide an improved understanding of a fire and provide the data that modeling groups need to better predict airborne and ground hazards.

Objectives : Large UAS provides a higher altitude view of the event and support teams to determine positions for the small UAS. Small UAS #1 is a tethered system at a fixed location to support teams to get real-time analysis of missions as they are ongoing and to support teams to evaluate effectiveness of missions and the implementation of the operational missions. Small UAS #2 provides thermal and visible-NIR data to map out the fire perimeter and provide broadband thermal infrared data to derived ground temperatures. Small UAS #3 provide aerosol and gas observations to map the plume and downwind cloud as well as atmospheric measurements to support air quality assessment team to derive atmospheric stability and mixing ratio. Small UAS #4 provides visible-NIR, TIR, and LiDAR data to map the downwind fire fuels to support the fire spread modeling team and fill data gaps. Evaluate how small UAS missions can respond to other small UAS operations and data analysis. Evaluate how 107 pilots can respond to operational needs where the launch site depends on fire location and downwind direction and how a suite of Part 107 operations can provide full aspects of wildland fire current size and likelihood to spread.

Mission Results

Observations : Recording of full extent of the fire as it progresses. lUAS data feeds back to EM Ops Center and to support sUAS teams to produce fine-scale data needed by ground team, AQ modelers and fire spread modeling team. sUAS #1 to support eyes on the event and communications hub if needed. sUAS #2 to map fire perimeter and intensity, sUAS #3 to measure plume height plus composition as well as atmospheric conditions, sUAS #4 to map fire fuels ahead of the fire spread and fill data gaps needed by the modeling team.

Real-time mission Products : lUAS provides RGB and TIR feeds to support ground teams on where to place sUAS. sUAS #1 is flown from set-location, that can move to location as defined needs arise, to support teams to get real-time analysis of missions as they are ongoing and to support teams to evaluate effectiveness of missions and the implementation of the CONOPS. sUAS #2 provides RGB-NIR/TIR data in real-time and observations to determine fire perimeter and intensity. sUAS #3 provides vertical profiles of plume/cloud top height and RH, T, and P to derive plume/cloud composition along with atmosphere stability and mixing height. sUAS #4 provides real-time feed of RGB-NIR and TIR data.

Post-Mission [fast response] Products : lUAS: Geospatial located video feeds to show field of view to analyze full extent of fire. sUAS#1: Full FOV of the missions with geo- and time-tagged data to compare to data from other sUAS and flight software. sUAS #2: Derived ground surface temperature of fire and perimeter. Mosaiced maps with derived properties of landscape along with DEM/DSM/3D models where SfM is possible. sUAS #3: Plume/cloud composition along sUAS route including vertical and horizontal profiles. Atmospheric data used to derive atmospheric stability and allow the AQ modeling team to measure mixing ratio. sUAS #4: LiDAR 3D point clouds of the upwind landscape and infrastructure ahead of the fire and where it is predicted to spread. Mosaiced maps with derived properties of landscape along with DEM/DSM/3D models where SfM is possible. Superimposed TIR and NIR/NDVI data on 3D models from RGB and LiDAR data.

Mission Procedures/Approach

Large UAS : Eyes above and support sUAS position
Take-off from nearby airport once report of fire. Site 1 in Oregon - Eugene if responding to Klondike/Taylor Creek '18 fire; Site 2 in Alaska - Anchorage if responding to Funny River '14 fire; Site 3 in New Mexico - Santa Fe if responding to El Rito '21 fire
Beyond line of sight (BVLOS) operations; Flown from runway to traverse to fire location
Route defined to reach site efficiently and then holding pattern to keep eyes on fire
Day of flying to reach site and provide high altitude eyes on disaster

Small UAS #1 : Tethered to watch other small UAS and communication link if needed
Stays airborne to watch all following missions; Take-off location dependent on fire location and any updates from large UAS data
Part 107 and visual line of sight (VLOS) operations; Fly VLOS or extended-VLOS under visual flight rules (VFR) conditions
This will act as fixed tethered view of all of the missions
Electro-optical visible and thermal data shared through tethered system; Sensor field of view allows full view of all operations [take-off, flight, and landings]

Small UAS #2 : Mapping of the fire to determine intensity and perimeter
Take-off location selected to support analysis of the fire size
Part 107 and VLOS operations; Electro-optical visible, NIR, and TIR camera suite
Provide real-time data and build mosaiced maps and three dimensional models
Route defined to cover the fire and map is thermal signal and edge

Small UAS #3 : Plume/Cloud details and atmospheric conditions
Take-off location selected based on location of the fire and plume; Mission design to measure plume top height and then direction and dimensions of cloud
Part 107 and may require EVLOS operations; Maybe instrument flight rules (IFR) conditions if the plume/cloud optically thick
Aerosol sampler, gasses sensor, with include relative humidity (RH), temperature (T), and Pressure
Real-time data to provide where plume top is detected; Sample the plume and follow dispersing cloud, manual flight based on the data at ground control station

Small UAS #4 : Fire fuels and landscape details ahead of fire spread and upwind of plume/cloud
Take-off location selected based on fire location and need for data where fire will spread
Gridded data collected to map the landscape ahead of the fire
Part 107 but might require EVLOS given distance to cover based on pilot in command location
Electro-optical visible, NIR, and TIR camera suite along with LiDAR, if possible, to measure height of vegetation and any canopy
Real-time electro-optical visible data streamed back so that manual flight can be selected if needed
Fire spread modeling team member with PIC to assess the areas that needs mapping

Mission Milestones

Outcomes/Actionable Intelligence
Large UAS [Higher altitude eyes] - Adaptable mission to map the full extent of the new fire seen from satellite data. Electro-optical visible and thermal infrared video data feedback to ground control station (GCS) and piped into operations center to determine where to send small UAS teams. GCS team in communications with operations center and small UAS teams.

Small UAS #1 [Eyes on missions and backup communications] - provides electro-optical visible and thermal data of all other small UAS missions to assess success to complete missions. Onboard communications can support radio connections between small UAS #2 - #4 and main operations center. These communications will act as mitigation measure to minimize risk that another communications network goes out

Small UAS #2 [hotspots] - Based on satellite data with accompanying spot weather forecast request, and local wildland fire alert. Part 107 pilot under VLOS goes to locations close to detected fire and fly patterns to collect electro-optical visible and thermal data. Videos feed in real-time back to GCS and piped to decision makers. Imagery taken to build a mosaicked map of visible data with superimposed thermal map. Real-time feed used by event chief to determine need for group ops. Products: Spot Detection and Fire Perimeter map

Small UAS #3 [plume/cloud content and atmospheric stability/mixing height] - Based on data from small UAS #1, these operations will fly downwind of the fire to measure any smoke particulates and gasses from the fire. Most likely will be flying EVLOS as it will need to fly beyond pilot location to map out the extent of the plume and cloud. It will gave a sampler onboard to get data back to GCS and displayed in real-time into the visualization tool. Data off the small UAS available to plume model community and provided to U.S. National Weather Service (NWS) for reporting on airborne particulates and if any significant gas content. It will have onboard atmospheric sensors to provide data to support derivation of mixing height and atmospheric stability of the atmosphere.

Small UAS #4 [ahead of fire fuels mapping] - This will be set up ahead of the fire locations seen in the satellite data and based on likely fire spread direction. Data will be collected to benefit the fire spread modeling, so will need this input first and define location for operations to provide data to fill a gap in their needs. It will be providing high resolution visible, multispectral data [visible+Red-edge+near-infrared] with where possible LiDAR of the landscape for fire fuels to support fire spread models. Real-time: Video feeds of electro-optical visible data. Fast-turn around: Vegetation indices and fuel-data from individual images. Post-mission: Mosaicked maps of vegetation indices and other products such as point clouds to assess high resolution maps of vegetation and local canopy.

Metrics of success
Large UAS streams data back to the incident center to support assessment of full extent.
Small UAS #1: Stays airborne, electro-optical visible and thermal infrared feeds back to GCS, tether continues to support data being streamed back and power to prevent need for new batteries
Small UAS #2 streams back data to support team to assess fire size and provides TIR data to derive fire intensity and map fire perimeter
Small UAS #3 provides aerosol data to determine constituents of cloud and plume as well as plume top height for air quality modeling team.
Small UAS #3 collects atmospheric data to support derivation of atmosphere stability and mixing ratio
Small UAS #4 maps the area ahead of the fire and data used to derive three-dimensional models of the landscape with superimposed visible, NIR, and TIR data.
Safe flight operations with multiple small UAS operating and data streaming back.
Both small UAS flew under Part 107 and VLOS is maintained.

1.8.2 Appendix 2: Flight Checklists

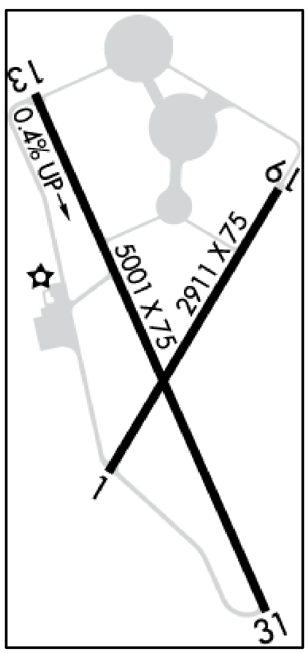
Aim: This appendix collects all flight checklists the mission team would complete pre-, during, and post-flight while at the mission location as well as pre- and post-operation before arriving and after leaving the mission location. Each flight checklist is included in a supplementary document. These 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

1.8.3 Appendix 3: Additional Requirements

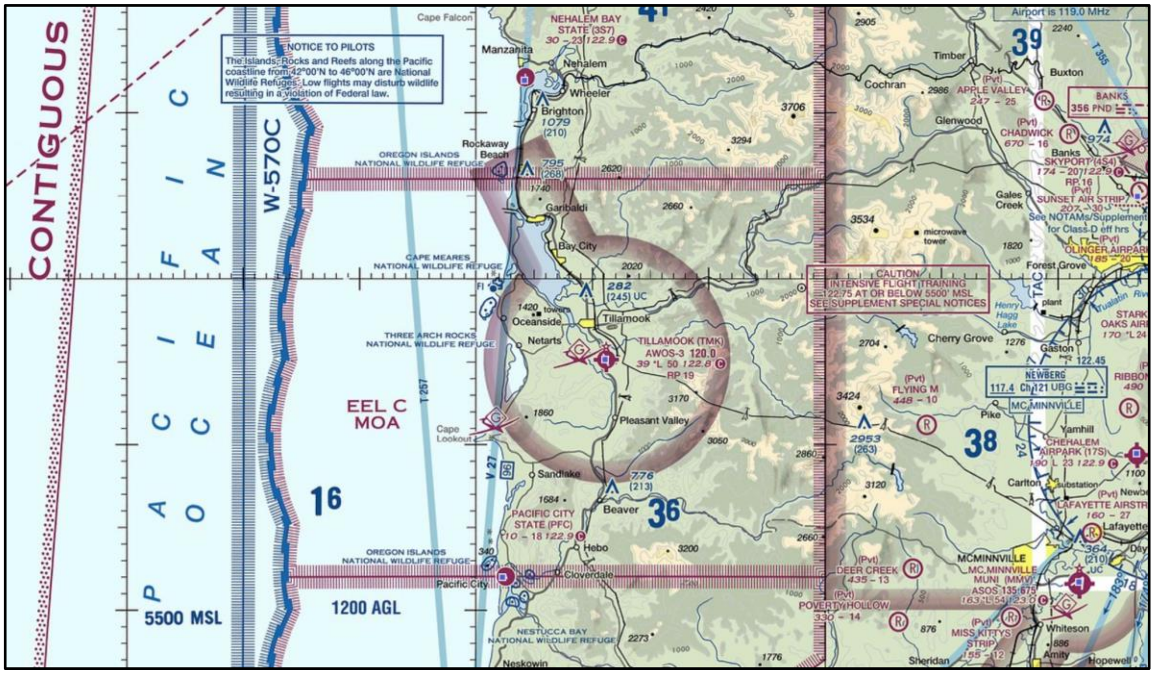
Tillamook Airport for large UAS from APOA



Sectional Charts

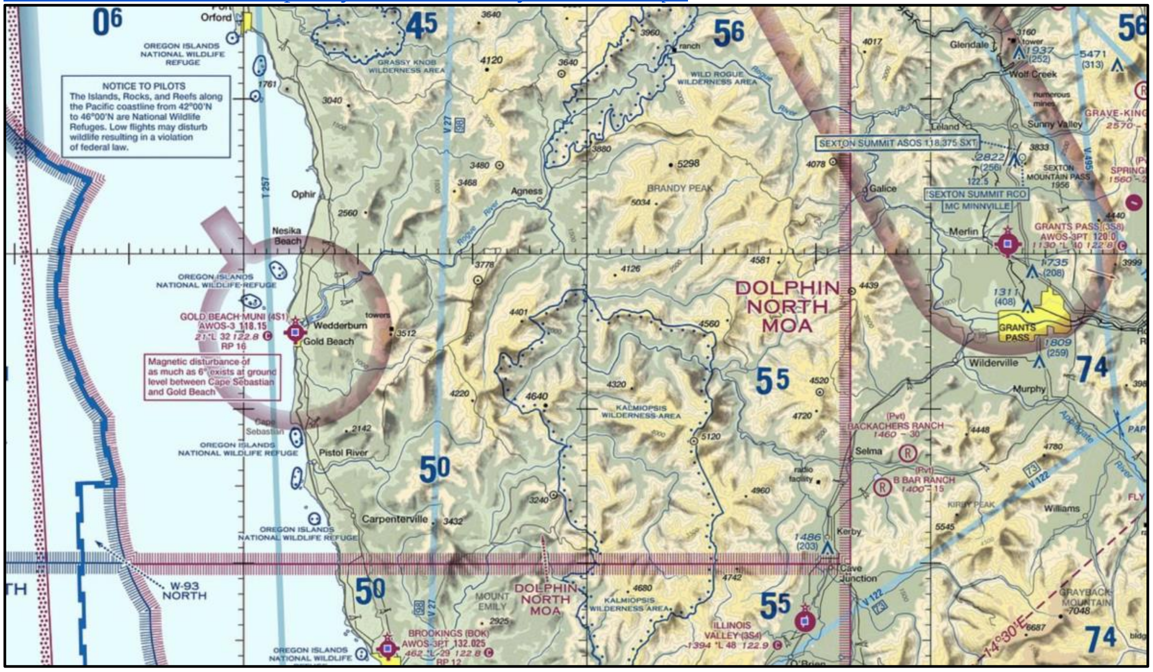
Tillamook and region

http://vfrmap.com/?type=vfrc&lat=45.418&lon=-123.814&zoom=10&api_key=763xxE1MJHyhr48DlAP2qQ



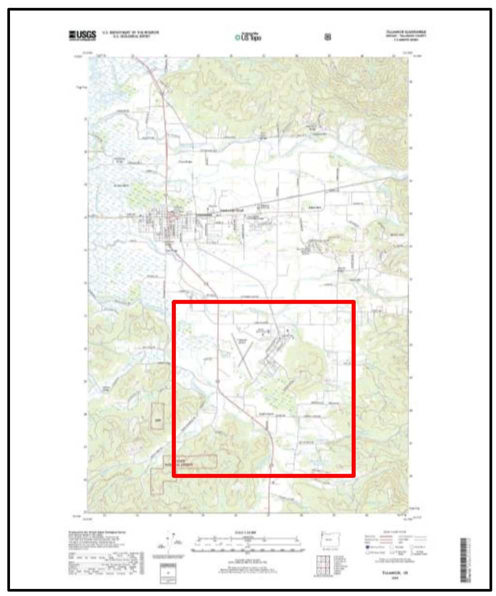
Klondike/Taylor Creek, Oregon

http://vfrmap.com/?type=vfrc&lat=42.3962206&lon=-123.901746&zoom=10&api_key=763xxE1MJHyhr48DlAP2qQ



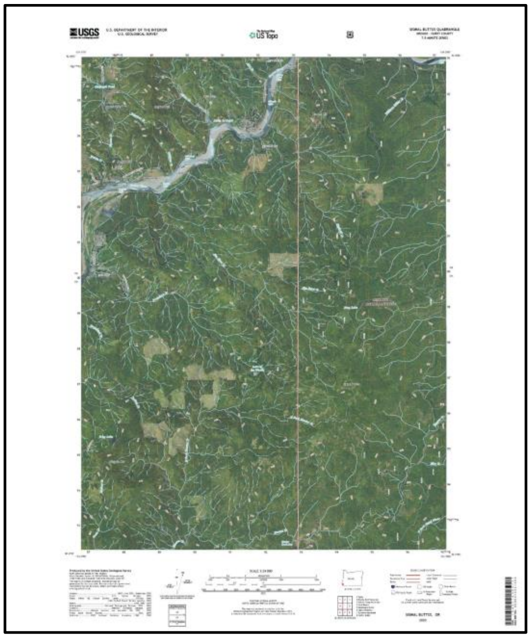
[USGS 7.5-minute maps](#)

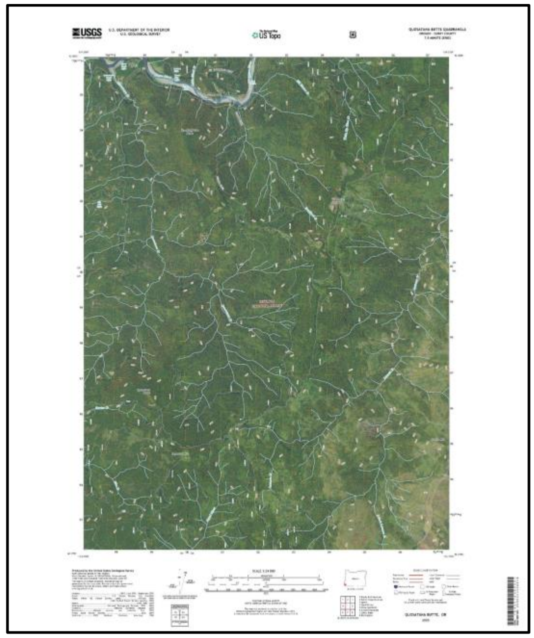
Tillamook and region - Online at [Tillamook](#)

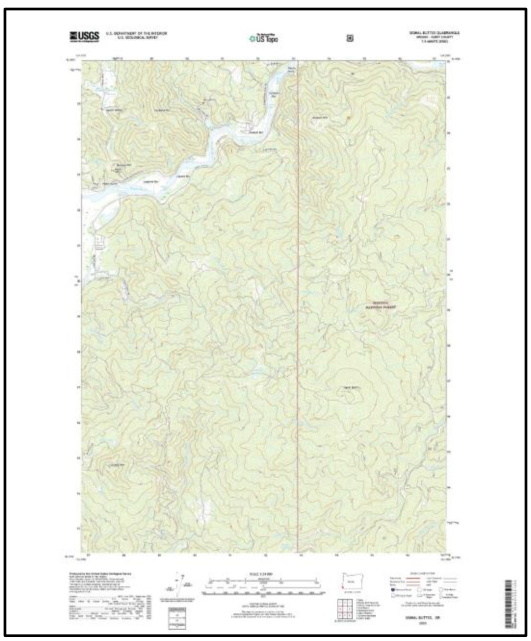


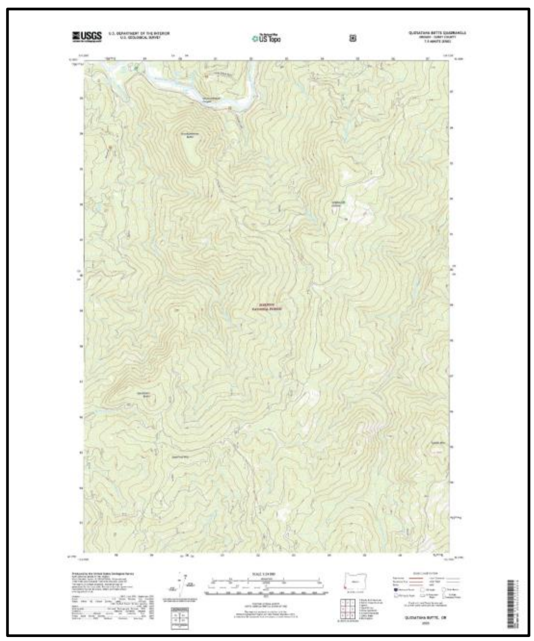
Klondike/Taylor Creek, Oregon

Signal Buttes and Quosatana Butte



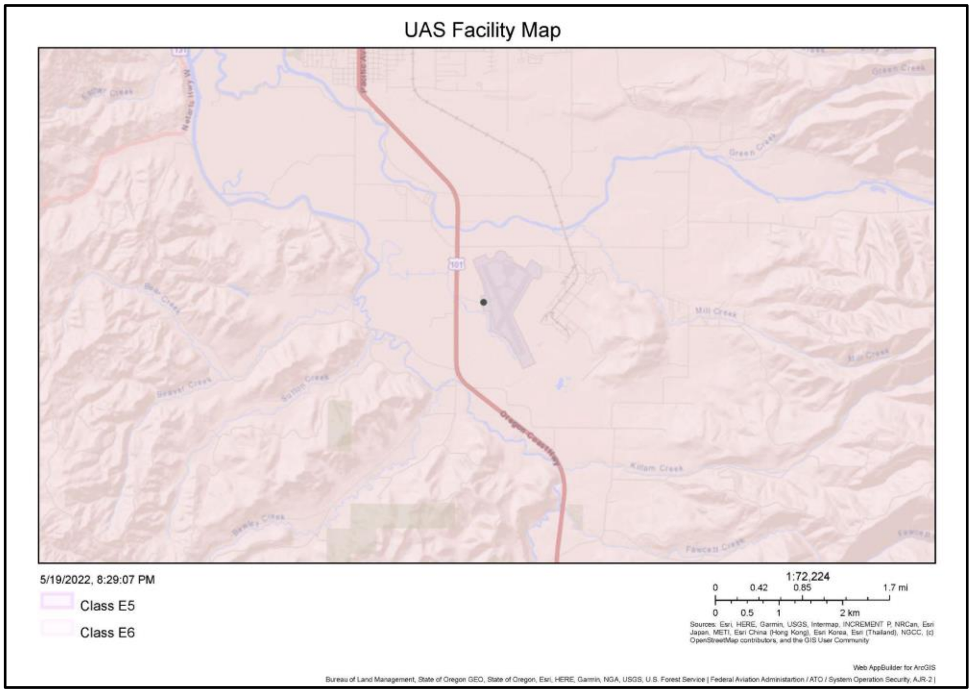




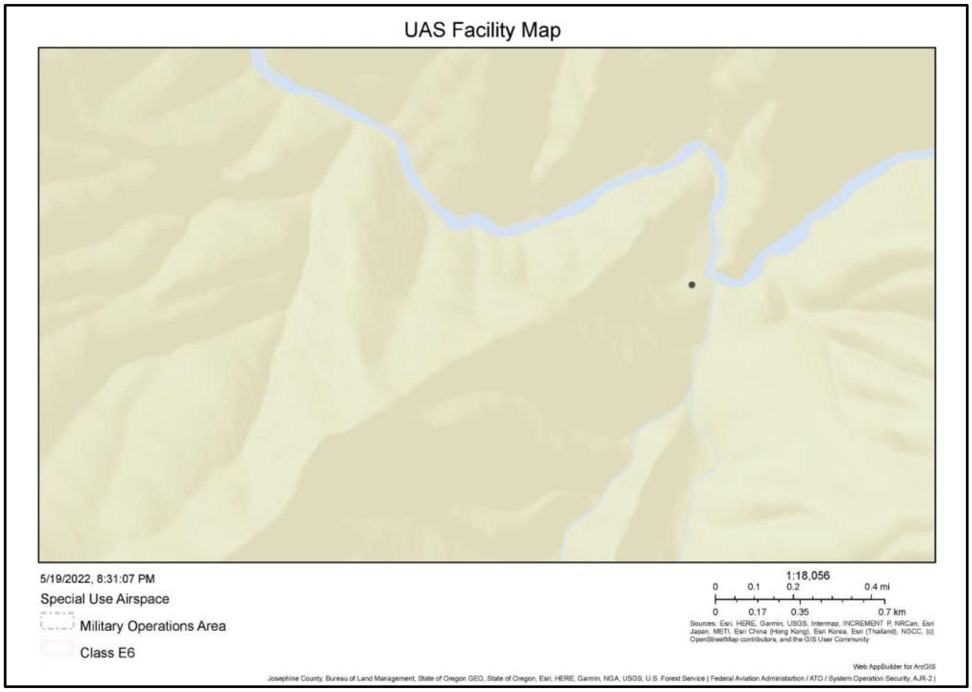


[LAANC Facility Maps]

Tillamook and region



Klondike/Taylor Creek, Oregon



1.8.4 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 Special Government Interests (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

1.8.5 Appendix 5: Data Archive Plan

<u>Processing specifications</u>

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

<u>File formats</u>

- Detailed descriptions: https://www.ogc.org/docs/is
- Electro-optical 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
- Electro-optical 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)
- Meteorological, wildland fire particulate, and gas data
    - US-American Standard Code for Information Interchange (ASCII)
    - 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
    - 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

1.8.6 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*