# Final Report
# ASSURE A28: Disaster Preparedness and Response Using UAS
# Appendix D - UAS Use Cases and Usage Challenges

June 1, 2022

## NOTICE

## LEGAL DISCLAIMER

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| | |
|---|---|
| BVLOS | Beyond Visual Line-of-Sight |
| COA | Certificate of Authorization |
| CONOP | Concept of Operation |
| DAA | Detect and Avoid |
| DEM | Digital Elevation Model |
| DSM | Digital Surface Model |
| EO | Electro Optical |
| EVLOS | Extended Visual Line-of-Sight |
| GCS | Ground Control Station |
| IFR | Instrument Flight Rules |
| LiDAR | Light Detection and Ranging |
| lUAS | Large Unmanned Aircraft Systems |
| NDVI | Normalized Difference Vegetation Indices |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PIC | Pilot In Command |
| PIREP | Pilot Report |
| SAR | Search And Rescue |
| SGI | Special Government Interest |
| sUAS | small Unmanned Aircraft System |
| TFR | Temporary Flight Restriction |
| TIR | Thermal Infrared |
| UAS | Unmanned Aircraft System |
| VLOS | Visual Line of Sight |
| VTOL | Vertical Takeoff and Landing |

# 1. –UNMANNED AIRCRAFT SYSTEM (UAS) USE CASES AND USAGE CHALLENGES

## 1.1 Use Case: Wildland Fire

### *1.1.1 Summary*

- Use Case 1: Response, Ongoing, Prescribed burn, small Unmanned Aircraft Systems (sUAS), Part 107 Visual Line of Sight (VLOS), Dropping Spheres/ Electro Optical (EO)/Thermal Infrared (TIR)/Light Detection and Ranging (LiDAR)
- Use Case 2: Response, Ongoing, Forest canopy, s(l)UAS, (B)VLOS/Certificate of Authorization (COA), EO/TIR
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- Use Case 6: Preparedness, Before, Past fire susceptibility mapping, Large Unmanned Aircraft Systems (lUAS), Beyond Visual Line of Sight (BVLOS), Optical/TIR/Multispectral
- Use Case 7: Response, Ongoing, Hotspot detection of new fires + map, Mapping fuels upwind of fire, s(l)UAS, BVLOS, Optical/TIR/Multispectral

Table 1. Wildfire Use Cases.

| Wildfire use cases | | | | | | | |
|---|---|---|---|---|---|---|---|
| Mission Details | #1 | #2 | #3 | #4 | #5 | #6 | #7 |
| Before/During / After | During | During | During | During | After | Before | During |
| Hazard details | Prescribed burn | Forest Canopy | Fire and Structure | Particulate dispersal sampling | Damage Assessment | At-risk locations/susceptibility mapping | Hotspot detection; fire behavior/Mapping potential fire fuels |
| Response/ Preparedness | Response | Response | Response | Response | Response | Preparedness | Response |
| Type of Flight | Part 107 | COA | COA | Part 107 Waiver | Part 107/COA | Waivers/COA | Part 107/Waivers/COA |
| Type of LOS | VLOS | BVLOS | BVLOS | BVLOS | (E→B)VLOS | BVLOS | VLOS and BVLOS |

| Wildfire use cases | | | | | | | |
|---|---|---|---|---|---|---|---|
| Type of UAS | sUAS | s(i)UAS | s(I)UAS | s(l)UAS | s(l)UAS | lUAS | S(l)UAS |
| UAS Design | Rotor | Rotor/Fixed wing | Rotor/Fixed wing | Rotor/Fixed wing | Rotor/Fixed wing | Fixed wing | Rotor/Fixed Wing |
| UAS Aircraft | TBD | TBD | TBD | TBD | TBD | TBD | TBD |
| Flight details | Real-time short flights to monitor event | Long term flights of forest | Monitoring fire and damage to buildings | Sampling of the plumes and clouds | Analysis of the fire burned area | Large scale mapping of past fire regions before fire season | Regional mapping of fires + rapid response to new fire sites and assess fire fuels |
| Payload | Dropping<br>Spheres/EO/TIR/LiDAR | EO/TIR | EO/TIR | Particulate sensor/EO/TIR | EO/TIR/LiDAR | EO/TIR/Multi-spectral | EO/TIR/Multi-spectral |
| Data Collected | Images and Video | Images and Video | Images and Video | Imagery, Video, and time series of samples | Images and Video | Images and Video | Images and Video |
| Product and Use | Real-time: Geotagged images/video, Fire suppression<br>Post-flight: Digital Surface Model/Digital Elevation | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | 3-dimensional (3D) profile of smoke concentrations | Post-flight: Geotagged images/video, DSM/DEM,<br>Orthomosaics | Post-flight: Geotagged images/video, DSM/DEM, Orthomosaics, Vegetation Maps | Post-flight: Geotagged images/video, DSM/DEM, Orthomosaics, Vegetation Maps |

| Wildfire use cases | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Model (DSM/DEM), Orthomosaics | | | | | | |
| Notes | Real-time data back to Ground Control Station (GCS) and shared with decision manager. | Real-time data back to GCS and shared with decision manager | Real-time data back to GCS and shared with decision manager. | sUAS if can reach fire site. lUAS if long distance. Build data on smoke amounts | Derived products of mapped fire perimeter | Data available to assess potential for past fires restarting | Spaceborne or ground data prompts team to determine need for UAS support |

### *1.1.2 Use Case #1: Prescribed burn wildland fire*

This Concept of Operation (CONOP) focuses on the collection of thermal and optical imagery and video of the prescribed burn as well as the application of a fire suppression payload.

This use case involves sUAS flown with VLOS operations and as a Part 107 mission. Payloads include optical and thermal infrared sensors as well as fire spheres for suppression. If possible, a LiDAR sensor could capture high resolution data to map the landscape.

The CONOP can also include fire starters for the prescribed burn. Here, a small UAS flies to the location for the burn so that personnel are not put at risk on the ground. Note that the burn can also occur in an area that is not accessible from the ground. IGNIS® aerial ignition payloads from Drone Amplified can be used. Ethylene glycol (antifreeze) is injected into a Dragon Egg (ping pong ball essentially) that contains potassium permanganate. There is a strong exothermic reaction that results in combustion that can be utilized to ignite wildland fuels.

This mission is flown with an individual UAS for the use case and with other UAS in the vicinity. This will test how the mission UAS interacts with a non-mission UAS and any airspace deconfliction that occurs. Another option is flying one UAS with the fire suppression payload and another with the combined optical and thermal infrared. These two UAS flown at different altitudes, where the suppression UAS is flown at lower heights and the second UAS maps the fire and measures the impact of the suppression on the fire intensity.

Post flight products include orthomosaic maps of the burn area as well as digital elevation and surface models of the flown flight area including prescribed burn and local landscape.

- Mission includes:
  - Multiple small UAS Part 107 VLOS flights
    - One suppression, one ignition, one optical/thermal infrared
  - Other sUAS in the vicinity – outside the mission zone
- Hazards include:
  - Prescribed burn – ignition and suppression
  - Ground fire
- Types of flight include:
  - During: Record burn area and temperature of surface
  - Drop spheres to ignite an area that cannot be reached by ground
  - Drop spheres to suppress the fire once it has burned
- UAS to be used:
  - Small UAS #1: Rotor with integrated EO/TIR for short flights
  - Small UAS #2: Rotor with payload capacity to carry fire suppression spheres
  - Small UAS #3: Rotor with payload capacity to carry fire ignition spheres
  - Small UAS #4: Non-mission specific UAS flying nearby
- Payload includes:
  - Dropping fire ignition and suppression spheres
  - Optical and thermal cameras
  - LiDAR where possible [depends on payload capacity of UAS]
- Products may include:
  - Real-time: Images and video to Ground Control Station (GCS)

  - Post-processed: Geotagged Imagery, Digital Surface Model/Digital Elevation Model (DSM/DEM), and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: A benefit is the CONOPS tests teams' ability to stream optical and/or TIR data back to the GCS to pass along to in the incident command. The operation evaluates how missions respond to other UAS and observers' communications with pilot in command. Dropping ignition spheres shows how UAS can be used to access remote sites that require burn but cannot be reached by those on the ground or the risk is too high for them or there is no helicopter to support access. Dropping of fire spheres demonstrates how these payloads could be used to suppress a wildland fire and how the flown UAS could provide the EO/TIR data at the same time. The second mission UAS provides real-time data on the effectiveness of the suppression system.

#### *1.1.3 Use Case #2: Forest canopy fire*

This is a CONOP collecting thermal and optical imagery and video of a forest canopy fire to understand its spatial extent across spatial extent of the forest as well as the vertical extent of the fire spread throughout the forest from canopy to ground. UAS are flown over the forest area to examine the full extent of the fire and at the level of the forest canopy top to examine if fire is jumping throughout the canopy or has spread further down into the forest.

A small UAS is flown with VLOS operations and Part 107 mission to map the canopy foliage and examine the thermal signals. A large UAS is flown above forest under Extended Visual Line of Sight (EVLOS) or BVLOS. The mission has small and large UAS operating at the same time and at different altitudes. A Temporary Flight Restriction (TFR) is in place given the air and ground hazard from the fire and need to limit other aircraft within the airspace.

Payloads include optical and thermal infrared sensors. Post flight products include orthomosaic maps of the burn area as well as digital elevation and surface models of the flown flight area including prescribed burn and local landscape.

- Missions include:
  - Small UAS: Part 107 VLOS to map fire extent vertically within canopy
  - Large UAS: BVLOS flights to map forest canopy fire extent
- Hazards include:
  - Forest canopy fire
- Types of flight include:
  - During: Mapping fire extent with large UAS; Fire vertical spread with small UAS. Both under Special Government Interest (SGI) waiver or with a TFR in place.
- UAS to be used:
  - Small UAS: Rotor with integrated EO/TIR for short flights
  - Large UAS: Fixed wing/Vertical Takeoff and Landing (VTOL) with long endurance and payload capacity for EO/TIR
- Payload includes:
  - Optical and thermal infrared cameras
- Products may include:
  - Real-time: Images and video to GCS
  - Post-processed: Geotagged Imagery, DSM/DEM models, and orthomosaic maps

Benefits include: A benefit is the CONOPS tests teams' ability to stream optical and/or TIR data back to the GCS to pass along to in the incident command. This operation evaluates how missions respond to other UAS and observers' communications with pilot in command. The large UAS flies in specific patterns while the small UAS changes its route based on direction from the decision support team who are viewing and analyzing the data in real-time. This helps to evaluate how the team can adapt flights in real-time based on input from those at incident command. It also helps to understand how TFR and SGI work together to support flight operations.

#### *1.1.4 Use Case #3: Wildland fire and structure fire*

This CONOP focuses on wildland fire as it spreads and the impact that the fire has on a structure in the path of the fire. UAS are flown over the landscape to examine the full extent of the fire and flown close to the structure to examine for damage, if the fire has spread to it, and its stability.

A small UAS is flown with VLOS operations and Part 107 mission to examine the structure. A large UAS is flown above wildland fire under EVLOS or BVLOS. TFR in place given air-hazard from fire to any aircraft.

This mission has both small and large UAS operating at the same time. The large UAS flies at higher altitudes to map the extent of the fire, while the small UAS flies routes based on the needs of the incident command team and adapting based on the fire spread and disaster response.

Payloads include optical and thermal infrared sensors. Post flight products include orthomosaic maps of the burn area as well as digital elevation and surface models of the flown flight area including area burnt and local landscape. Additional data include maps of the structure to be used for building damage assessment.

- Missions Include:
  - Small UAS: Part 107 VLOS to map structure and fire extent
  - Large UAS: BVLOS flights to map wildland fire extent
- Hazards include:
  - Wildland fire with structure
- Types of flight include:
  - During: Map fire extent with large UAS; Structure fire and building stability with small UAS. lUAS flies defined pattern while sUAS flies adaptable routes. TFR with SGI waiver.
- UAS to be used:
  - Small UAS: Rotor with integrated optical/TIR for short flights
  - Large UAS: Fixed wing/VTOL. Long endurance and payload capacity for optical/TIR
- Payload includes:
  - Optical and thermal infrared cameras
- Products may include:
  - Real-time: Images and video to GCS
  - Post-processed: Geotagged Imagery, DSM/DEM models, and orthomosaic maps

Benefits include: A benefit is the CONOP tests teams' ability to stream optical and/or TIR data back to the GCS to pass along to in the incident command. The operation evaluates how missions respond to other UAS and observers' communications with pilot in command. This tests the ability of two mission teams to work together with one operating large UAS and one the small UAS. The small UAS would adapt routes to the needs of the incident command team. This also tests how small UAS teams deal with requests to the Pilot in Command (PIC) and GCS while also managing non-mission specific attendees to the flights.

#### *1.1.5 Use Case #4: Wildland fire smoke plume and downwind cloud sampling*

This CONOP is to sample (1) plume at active fire and (2) downwind clouds to assess potential impact to population, infrastructure, and transportation networks. Sampling fire plume and downwind cloud could be completed with one mission, depending on the endurance of the UAS. UAS fly through plumes and clouds without putting personnel at-risk. This is not usually done by manned flights as risk is too high.

The focus is to collect optical and thermal data of the plumes and clouds and measurements of the smoke particulate levels emitted. BVLOS operations are needed with possible waivers and COA. Large UAS are needed given distance to fire location and remoteness. Onboard Detect and Avoid (DAA) and/or ground-based tracking capabilities are useful. Note that a TFR is likely in place over the fire location. Pilot Reports (PIREPs) from manned flights or ground observations support mission team to assess area to map for downwind clouds.

The fire emission mission will follow a specific route as well as some manual operations to sample the developing plume. A downwind cloud mission will require manual operations as the cloud disperses and is transported by the atmospheric winds.

Payloads include EO and TIR sensors along with capability to measure smoke particulate concentrations. Products include optical and thermal orthomosaic maps of the fire along with 3D profiles of the smoke concentrations. Data and products are provided to the local weather agency to support their decision-making process on airborne hazards and comparison to modeling of smoke concentrations. The data and products are also sent to incident command/emergency command center.

- Missions Include:
  - EVLOS/BVLOS to sample particulates from fire-based plumes and downwind clouds
  - Waivers/COA needed. Main need rapid response SGI. TFR in place at fire location.
  - Continued sampling of plume from active fire as well sampling of downwind clouds
- Hazards include:
  - Smoke particulates released by plumes at fire location and clouds transported downwind
  - Population centers and infrastructure at-risk
  - Downwind impact to aviation community and local communities
- Types of flight include:
  - Measure smoke particulates. Ability to re-sample based on data collected
  - TFR/SGI in place as active fire and do not want other aircraft in the vicinity
  - Flight into and out of TFR, as this would only over the active region
  - Flight team need COA in place for operations
- UAS to be used:
  - Fixed wing/VTOL large UAS with long endurance and payload capacity
  - Small UAS sampling plumes and smoke particulate concentrations if access possible

- Payload includes:
  - Optical and thermal infrared cameras
  - Particulate sampling equipment [0.1 – 100 µm] as well as T/P/RH atmos. sensors
- Products may include:
  - Real-time: Images and video to GCS and onto incident command
  - Post-processed: Geotagged Imagery, DSM/DEM, mapped fire area in optical and thermal format as GIS data, 3D models of impacted area, and orthomosaic maps

Benefits include: Equivalent flights to manned aircraft are used to assess UAS capacity to support disaster response. This operation includes BVLOS operations and possible SGI/COA/TFR. Depending on flight location, the operations may use Instrument Flight Rules (IFR) only. Real-time and/or post processing of plume/clouds are used for decision making at incident command and/or weather agency. Both pre-defined routes and manual operations are tested. The operation also assesses how unmanned mission critical aircraft operate to support decision making while non-mission critical aircraft are within vicinity. Note that aircraft may need to take-off and land at locations outside a TFR, so a SGI waiver and/or other permissions for airspace would be needed.

#### *1.1.6 Use Case #5: Damage assessment from wildland fire*

This CONOP describes the mission after the wildland fire has ended. The intent is to collect optical and thermal imagery and video of damage caused fire spread. The focus is to collect data to map spatial extent of the fire's impact and to support recovery.

The CONOP supports large scale mapping mission over the area impacted by a wildland fire. The mission occurs as soon as the imminent hazard is over and/or includes multiple missions to assess how the landscape/infrastructure responds after the end of the fire.

The data collected supports those in fire prediction modeling and early detection with high spatial resolution data to add to any past fire mapping and to increase knowledge of the local vegetation that would act as fuels for any future wildland fires.

Optical data provides observations to build DEM/DSM of the flown area and orthomosaics while thermal (7 – 13 µm) or medium (~ 3.75 µm) infrared is used to detect any thermally active regions of the wildland impacted area. Multispectral sensors support the development of derived products such as Normalized Difference Vegetation Indices (NDVI) for comparison to other data including ground measurements and satellite data.

Payloads include EO and TIR sensors, and where possible multispectral sensors. Post flight products include orthomosaic maps of the damage from the fire products and digital surface models of the flown flight area. If possible, a LiDAR sensor could capture high resolution data to map the landscape.

- Missions Include:
  - BVLOS operations would map extent of fire. Waivers may be needed.
  - Assess the impact to landscape and infrastructure.
  - Provide data to support state organization to map fire and impact to vegetation.
- Hazards include:
  - Wildland fire will impact structures and vegetation.
  - Fire will cause major damage to infrastructure.

- Recovery assessment is needed.
- Types of flight include:
  - Post-event: Large-scale mapping with optical and thermal cameras is required.
- UAS to be used:
  - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR is used.
- Payload includes:
  - Includes optical and IR cameras, including multispectral to assess impact to vegetation.
  - LiDAR is used where possible [depends on payload capacity of UAS].
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, mapped fire area in optical and thermal format as GIS data, 3D model of impacted area, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: A benefit is the CONOP tests teams' ability to collect optical and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and observers' communications with pilot in command. This would allow a post-event operation to build assessment maps of the full extent of the damage. Large UAS missions are flown recently after the fire ends as well as systematically to assess recovery of the landscape and any infrastructure. The response team would develop a COA to support missions and evaluate how to update CONOP and/or operational risk assessment based on needs of the decision makers on areas at risk. They would also evaluate the need for more observational data.

### *1.1.7 Use Case #6: Pre-fire season susceptibility mapping of at-risk zones*

This CONOP focuses on collecting high resolution optical, thermal/medium infrared and multispectral infrared observations over past wildland fire hotspots in the spring prior to the main fire season. Data collected supports those in fire prediction modeling and early detection with high spatial resolution data to supplement past fire histories and increase knowledge of the local vegetation that would act as fuels for any future wildland fires. Optical data provides observations to build DEM/DSM of the flown area and orthomosaics while thermal (7 – 13 µm) or medium (~ 3.75 µm) infrared is used to detect any early onset of past fires that still might be thermally active. Multispectral sensors support the development of derived products such as NDVI for comparison to other data including ground measurements and satellite data.

Coordination with the fire modeling community and state/local fire suppression and response organization determines the type of observation needed. This defines the altitude of the missions, area to cover, and sensor suite. BVLOS flights will include on-board DAA system as well as (if required) ground-based tracking from GCS for large UAS missions. Short campaign missions could be used to supplement over smaller regions around more recent fires. Payloads include EO and TIR sensors. Post flight products include orthomosaic maps of the damage from the fire products and digital surface models of the flown flight area. If possible, LiDAR sensors capture high resolution data to map the landscape.

- Missions include:
  - Small UAS conducting VLOS short flights at recent fires from past season.

  - Large UAS conducting BVLOS operations to map areas of past fire season to assess risk.
  - Part 107 waivers for sUAS and or waivers needed to support lUAS BVLOS.
  - Provision of data to support state organization to map fire and impact to vegetation.
- Hazards include:
  - Preparedness of CONOP to support decision support.
  - Lack of high-resolution maps of vegetation to support mapping at locations of past fires.
  - Need for improved knowledge of fire fuels by fire modeling community.
- Types of flight include:
  - Pre-event: Small and large-scale mapping with EO, multispectral, and TIR cameras.
- UAS to be used:
  - Small UAS: VTOL with multispectral camera and EO for comparison.
  - Large UAS: Fixed wing with long endurance and payload capacity for multi/TIR/EO.
- Payload includes:
  - Optical, multispectral, and thermal infrared cameras.
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM, past-fire mapped area as optical/multi- and thermal GIS data, NDVI data including additional products needed for fire modeling and orthomosaic maps.

Benefits include: This CONOP tests teams' ability to collect optical, multispectral and/or TIR data over a large area. This would be a pre-event operation to build assessment maps of potential for past-fire areas being a risk for future events and collected data needed to support the fire modeling community during a future disaster event. CONOP includes both small and large UAS with COA needed for BVLOS or at least Part 107 waivers to support small UAS operations.

#### ***1.1.8 Use Case #7: New hotspot fire, Mapping fire and upwind fuels, Data for modeling***

This CONOP focuses on collecting high resolution optical, thermal/medium infrared and multispectral infrared observations of a new wildland fire. Spaceborne data, ground-based personnel, and/or webcam observations detect and report a new fire and a need for airborne fine-scale mapping of the feature. Data collected helps those in decision support to assess the extent of the fire and its thermal input (difficult to resolve in spaceborne data), and locate fire perimeter (difficult to define from ground-based assets, personnel or webcams).

Optical data provides observations to build DEM/DSM of the flown area and orthomosaics while thermal (7 – 13 μm) or medium (~ 3.75 μm) infrared is used to detect the hotspot. Multispectral sensors support the development of derived products such as NDVI for comparison to other data including ground measurements and satellite data. Also, this will assist those modeling the fire fuels that could then cause rapid expansion of the fire.

Coordination with fire modeling community and state/local fire suppression and response organization will determine the type of observation needed. This will define the altitude of the missions, area to cover, and sensor suite.

lUAS flies above the area of detection with BVLOS flights and on-board DAA system. Short campaign sUAS missions supplement over smaller regions around hotspots seen in other datasets.

Payloads include EO and TIR sensors, and where possible multispectral capability. Post flight products include orthomosaic maps of the fire perimeter and data needed by fire modeling community.

- Missions Include:
    - Small UAS: VLOS short flights to map area of new hotspots seen in other data.
    - Large UAS: BVLOS operations to map fire area and surrounding landscape.
    - Part 107 waivers for sUAS and or waivers needed to support lUAS BVLOS.
    - Provision of data to support state organization to map fire and impact to vegetation.
- Hazards include:
    - Preparedness CONOP to support decision support.
    - High-resolution maps of vegetation to support mapping at fire fuels.
    - Decision making teams needs fine scale observations of new fire sites.
    - Fire modeling community needs improved knowledge of fire fuels.
- Types of flight include:
    - Pre-event: Small and large-scale mapping with EO, multispectral, and TIR cameras.
- UAS to be used:
    - Small UAS: VTOL with multispectral camera and EO for comparison.
    - Large UAS: Fixed wing with long endurance and payload capacity for multi/TIR/EO.
- Payload includes:
    - Optical, multispectral, and thermal infrared cameras.
- Products may include:
    - Post-processed: Geotagged Imagery, DSM/DEM, past-fire mapped area as optical/multi- and thermal GIS data, NDVI data including additional products needed for fire modeling and orthomosaic maps.

<u>Benefits include:</u> The CONOP tests teams' ability to collect optical, multispectral and/or TIR data rapidly to supplement spaceborne and ground-based sensors. This would be a real-time response mission to rapidly respond to new fire locations. CONOP includes both small and large UAS with COA needed for BVLOS or at least Part 107 waivers to support small UAS operations.

## 1.2 Use Case: Oil Spill

### *1.2.1 Summary*

- Use Case 1: Response, During, on water, sUAS and lUAS, EO and thermal payloads, (E→B)VLOS
- Use Case 2: Response, Post-event damage assessment, on water, sUAS and lUAS, EO and thermal payloads, (E→B)VLOS
- Use Case 3: Response, During, on land, sUAS and lUAS, EO and thermal payloads, (E→B)VLOS
- Use Case 4: Response, Post-event damage assessment, on land, sUAS and lUAS, EO, multispectral, and thermal payloads, (E→B)VLOS

Table 2. Oil Spill Use Cases.

| Oil spill use cases | | | | |
|---|---|---|---|---|
| Mission Details | #1 | #2 | #3 | #4 |
| Before/During/After | During | After | During | After |
| Hazard details | Spill on water | Shoreline damage assessment<br>from spill on water | Spill on land | Damage assessment from spill<br>on land |
| Response/Preparedness | Response | Response | Response | Response |
| Types of flight include: | Part 107 and COA/Waivers | COA/Waivers | Part 107 | COA/Waivers |
| Type of LOS | VLOS ad BVLOS | (E→B)VLOS | VLOS | (E→B)VLOS |
| Type of UAS | sUAS and lUAS | lUAS | sUAS | lUAS |
| UAS Design | Rotor, fixed wing, VTOL | Fixed wing | Rotor, fixed wing VTOL | Fixed wing |
| UAS Aircraft | TBD | TBD | TBD | TBD |
| Flight details | Short, from water's edge of off<br>boat and long large UAS mission | Large scale surveillance of full<br>extent of spill | Short, analysis of oil spill from<br>pipeline | Large scale surveillance of full<br>extent of spill |

| | | | | |
|---|---|---|---|---|
| Payload | EO/TIR/PAH | EO/TIR | EO/TIR/PAH | EO/TIR/LiDAR/Multispectral |
| Data Collected | Images and Video, concentration | Images and Video | Images and Video, concentration | Images and Video |
| Product and Use | Real-time: Images/video Post-flight: Geotagged images/video, DSM/DEM, Orthomosaics, 3D concentration maps. Oil detection and human health and safety | Post-flight: Geotagged images/video, DSM/DEM, Orthomosaics. Oil detection | Real-time: Images/video Post-flight: Geotagged images/video, DSM/DEM, Orthomosaics, 3D concentration maps. Oil detection and human health and safety | Post-flight: Geotagged images/video, DSM/DEM, Orthomosaics. Oil detection |
| Notes | Real-time data back to GCS and shared with decision manager. | Derived maps of the oil spill extent that requires clean up | Real-time data back to GCS and shared with decision manager. | Derived maps of the oil spill extent that requires clean up |

### 1.2.2 *Use Case #1: Oil spill on water*

CONOP is to detect and monitor an oil spill originating from a water-surrounded point source (an exploration platform, production platform, underwater pipeline or from a pipeline terminal) into the local surrounding water. UAS is outfitted with visible and thermal infrared sensor payloads. Nearby shoreline assessments of percent oiling and wildlife impacts is included in operations.

Operations currently are performed by manned aviation flights, either in fixed wing aircraft or helicopters carrying trained visual observers utilizing optical and thermal sensors that are handheld or mounted to the aircraft, or via ground survey facilitated by small boats. All air operations as part of a mid to large-scale response will take place within airspace that is subject to a response-specific TFR.

Small UAS: sUAS flights are flown from either the shoreline or a boat in water to provide immediate situational awareness of oil impacts and to map the origin of the leak and the extent up to a mile in distance from the source (VLOS). sUAS are used to assesses if the leak is contained and to survey if any damage to the oil platform/terminal. sUAS are flown to determine the locations of wildlife relative to the oil spill including species, group size and heading to determine management strategies, or to identify animals in the immediate area. sUAS are used to determine critical habitat and other environmentally sensitive areas identified for response support. Where possible, the team will employ a sUAS outfitted with Polycyclic Aromatic Hydrocarbons (PAH) sensors to map extent of the Hot Zone in which human operations should be restricted.

Large UAS: Large UAS is used requiring launch and recovery from land. Large UAS is flown to map the full extent of the spill (BVLOS) and to monitor all operations from greater altitudes than achievable by sUAS. Large UAS will provide long-term monitoring of the response through high altitude surveys throughout the response. Large UAS is flown to determine the locations of wildlife relative to the oil spill including species, group size and heading to determine management strategies, or to identify animals in the immediate area.

All UAS: All UAS missions conducted during an organized response are coordinated through the Air Boss, part of the Operations group of the response. Oil spill on water missions have small and large UAS operating at the same time, and in the same airspace as manned aviators. Payloads include EO and TIR sensors, and air quality sensors (sUAS). Post flight products include maps of the spill extent in water, images of response equipment deployment configurations and efficacy, video, and images of oiled shoreline, orthomosaics of oiled shoreline and their corresponding digital surface models of the flown flight area and 3D maps of air quality Hot Zones.

- Missions Include:
    - Small UAS: Part 107 VLOS provide situational awareness of the immediate area, to map oil spill leak within VLOS, to document damage to terminal/platform, to determine if oil leak is on-going or contained, and to determine hazardous air quality.
    - Large UAS: BVLOS and Waivers/COA to map full oil spill extent including oiled shorelines, to monitor on-going response operations, and to identify current and potential impacts to wildlife of oil and response.
- Hazards include:
    - Oil spill on water, oiled shorelines, oiled wildlife, human health.
- Types of flight include:

    - During: Situational awareness, map extent of spill, assess ongoing flow into water, evaluate terminal/platform damage, determine current and potential wildlife impacts, determine current and potential shoreline oiling, provide air quality assessment.
- UAS to be used:
    - Small UAS: Rotor/fixed wing/VTOL. Integrated EO/TIR or PAH sensor. Short flights.
    - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR.
- Payload includes:
    - Optical and thermal infrared cameras.
    - PAH sensors (sUAS only).
- Products may include:
    - Real-time: Images and video to GCS and/or command post.
    - Post-processed: Geotagged imagery, geotagged videos, DSM/DEM models, and orthomosaic maps.

Benefits include: CONOP tests teams' ability to stream visible and/or TIR data back to the GCS and delivery, via livestream or other method, to the incident command, and to provide air quality determinations in support of responder safety. Operations evaluate how missions are coordinated through incident command (Air Boss) UAS Technical Specialists and the Pilot in Command. This would be to evaluate how UAS can provide near real-time data of oil spill conditions to decision-makers of the response.

#### *1.2.3 Use Case #2: Damage assessment of oil spill on water*

This CONOP collects thermal and visible imagery and video of an oil spill impact after the event. UAS mission focus is to collect data to map damage to oil terminal/platform, shorelines, and wildlife impacted. Operations currently performed by manned aviation flights, either in fixed wing aircraft or helicopters carrying trained visual observers utilizing optical and thermal sensors that are handheld or mounted to the aircraft, or via ground survey facilitated by small boats.

Small UAS flown to map any damaged infrastructure and to collect high resolution or unique assessments of the shoreline, inclusive of oiled wildlife and critical habitat. Potential that sUAS operations flown from boats if oil spill occurs away from the shoreline. Large UAS flown to map the full extent of the spill impacts to shorelines, inclusive of critical habitats and other environmentally sensitive areas for wildlife and commerce.

Payloads include EO and TIR sensors. Post flight products include wildlife point locations, orthomosaic maps of the spill impacts to shorelines as well as digital surface models of the flown flight area. Additional post-processed data include identification of the oil spill extent and persistent damage resulting from the oil or the response that could be used to calculate legal liability of the oil spill and corresponding response.

- Missions Include:
    - BVLOS operations to map extent and nuances of oil spill impact
- Hazards include:
    - Major impact to local environment from oil spill; Recovery assessment needed
- Types of flight include:

    - Post-event: Map extent of impacted shoreline, determine persistent damage to the shoreline, assess impacted wildlife, evaluate terminal/platform damage.
- UAS to be used:
    - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR
    - Small UAS: VTOL with fast turnaround to map impacted areas, Flown from shoreline and/or from boats for oil spills away from coast
- Payload includes:
    - Optical and thermal infrared cameras
- Products may include:
    - Post-processed: Geotagged Imagery, DSM/DEM models, orthomosaic maps, identification of persistent damage, 3D model of platform/terminal.

Benefits include: CONOP tests teams' ability to collect legally defensible visible and/or TIR data over a large area. Operations evaluate missions response to legally binding data requirements (including chain of custody) and other UAS and observers' communications with pilot in command. This would be a post-event operation to build assessment maps of the full extent of the damage.

#### *1.2.4 Use Case #3: Oil spill on land*

CONOP is to collect thermal and optical imagery and video of an ongoing oil spill from a pipeline and its impact on the local landscape.

Operations currently performed by manned aviation flights, either in fixed wing aircraft or helicopters carrying trained visual observers utilizing optical and thermal sensors that are handheld or mounted to the aircraft, or via ground surveys. All air operations as part of a mid to large-scale response will take place within airspace that is subject to a response-specific TFR.

Small UAS flown to provide situational awareness in support of tactical decision-making and general site reconnaissance, inclusive of nearby wildlife. Small UAS flown to map oil from a location immediately adjacent to the spill to map the location of original leak and extent of oiling using visible and thermal signals and assess the likelihood of continued spillage. Large UAS flown to map the full extent of the spill and the full extent of damage to the oil pipeline. Missions have both sUAS and lUAS operating at the same time.

Payloads include EO, TIR, and PAH sensors. Post flight products include orthomosaic maps of the spill and surrounding landscape, digital surface models of the flown flight area, point locations of oiled wildlife and 3D models of air quality in support of human health and safety. Additional post-processed data include an assessment of the oil spill extent.

- Missions Include:
    - Small UAS: Part 107 VLOS for situational awareness, to map oil spill leak, observe tactical response and assess damage to pipeline
    - Large UAS: BVLOS and Waivers/COA to map impacts to infrastructure
- Hazards include:
    - Oil spill on land with potential impacts to landscape
    - Wildlife habitat impacted
    - Continued oil spill from infrastructure and spreading across landscape

- Types of flight include:
    - During: Map extent of spill, impacts to wildlife, assess ongoing flow from pipeline, evaluate pipeline damage
- UAS to be used:
    - Small UAS: Rotor/fixed wing/VTOL with integrated EO/TIR/PAH for short flights
    - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR
- Payload includes:
    - Small and large UAS: Optical and thermal infrared cameras
    - sUAS: PAH sensor
- Products may include:
    - Real-time: Images and video to GCS, potentially incident command post
    - Post-processed: Geotagged Imagery, DSM/DEM models, wildlife point GIS data, and orthomosaic maps

Benefits include: CONOP tests teams' is able to stream visible and/or TIR data back to the GCS and delivery, via livestream or other method, to the incident command, and to provide air quality determinations in support of responder safety. Operations evaluate how missions are coordinated through incident command (Air Boss) UAS Technical Specialists and the Pilot in Command. This serves to evaluate how UAS can provide near real-time data of oil spill conditions to decision-makers of the response.

#### *1.2.5 Use Case #4: Damage assessment from oil spill on land*

CONOP is to collect thermal and visible imagery and video of an oil spill impact after the event. Focus is to collect data to map oil extent to the landscape and any nearby water and to map damage to oil pipeline. These operations currently are performed by manned aviation flights, either in fixed wing aircraft or helicopters carrying trained visual observers utilizing optical and thermal sensors that are handheld or mounted to the aircraft, or via ground surveys. Large UAS are flown to map the full extent of the spill and the full extent of damage to the oil pipeline as well as the local landscape. Local responders or operations team also flies small UAS at lower altitude to capture higher resolution data of the impacted landscape. Part 107 waivers are possibly needed for sUAS operations.

Optical data provides observations to build orthomosaics while multispectral sensors support the development of derived products such as NDVI for comparison to other data including ground measurements and satellite data. Also, multispectral data are used to assess vegetation health and impact of the oil spill on the landscape. Payloads include EO, TIR, and multispectral, and LiDAR sensors. Post flight products include orthomosaic maps of the spill and vegetation as well as digital surface models of the flown flight area. If possible, a LiDAR sensor captures high resolution data to map detailed impacts to the landscape. Additional post-processed data include an assessment of the oil spill extent.

- Missions Include:
    - BVLOS operations to map extent of oil spill impact on land.
    - Damage assessment of oil pipeline infrastructure.
- Hazards include:
    - Major impact to local landscape from oil spill.

- Recovery assessment is needed.

- Types of flight include:
  - Post-event: Map extent of total spill, evaluate pipeline damage, assess damage to the landscape from oil and response.
- UAS to be used:
  - lUAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR/LiDAR.
  - sUAS: VTOL for short period flights to provide higher resolution observations, multispectral camera and EO for comparison.
- Payload includes:
  - Optical and thermal infrared cameras with multispectral sensors.
  - LiDAR where possible [depends on payload capacity of UAS].
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, 3D model of pipeline and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

<u>Benefits include:</u> CONOP tests teams' ability to collect legally defensible visible and/or TIR data over a large area. Operations would evaluate how missions respond to legally binding data requirements (including chain of custody) and other UAS and observers' communications with pilot in command. This would be a post-event operation to build assessment maps of the full extent of the damage.

## 1.3 Use Case: Pandemic

### *1.3.1 Summary*

- Use Case 1: Response, sUAS, Mission: Medical delivery from hospital to clinic in city, (E→B)VLOS
- Use Case 2: Response, lUAS, Mission: Package delivery hub to smaller community, Airport-Airport, BVLOS

Table 3. Pandemic Use Cases.

| Pandemic use cases | | |
|---|---|---|
| Mission Details | #1 | #2 |
| Before/During/After | During | During |
| Hazard details | Medical Delivery | Community Supplies |
| Response/Preparedness | Response | Response |
| Type of Flight | Part 107 + waivers | COA |
| Type of LOS | (E→B)VLOS | BVLOS |
| Type of UAS | sUAS | sUAS and lUAS |
| UAS Design | Rotor | Fixed wing |
| UAS Aircraft | TBD | TBD |
| Flight details | Hospital to Clinic Delivery, Short Flight | Main hub to smaller community, multi-hours |
| Payload | Medical supplies and EO for situational awareness | Supplies for community |
| Data Collected | Optical images of route, route log | Optical images of route, route log |
| Product and Use | Record of delivery of medical supplies | Record of delivery of supplies |
| Notes | Focused on flying to and from a main hospital to a clinic to show how supplies can be sent via UAS | Focused on showing how UAS can get supplies from a main hub to smaller community both during pandemic and as a regular route |

### *1.3.2 Use Case #1: Medical delivery in community from hospital to clinic*

CONOP supports the delivery of medical supplies from a main hospital in a community to a local clinic. Here, the main hospital would be sending medical supplies from their roof to the clinic roof or parking area so that no one needs to travel between the facilities. Focus shows take-off from one site and landing at second location. Package would be delivered, and aircraft would then return to main hospital. There would need to be a person to meet the aircraft at the clinic and then be able to connect with the flight team or operator at the hospital so that the sUAS can then takeoff when supplies have been handed over.

Small UAS will fly under Part 107 and VLOS operations, if the two locations and airspace support these operations. If PIC or visual observer cannot continue to keep track of the aircraft and airspace, then BVLOS and waivers are issued to support the operation. Payloads include optical camera to provide real-time feed to GCS and at the landing site. Medical supplies would be an additional payload. Mission needs ground tracking capabilities to support operations, depending whether under a waiver/COA or not.

Small UAS may be flying in airspace with other possible UAS and manned aviation. Therefore, the team could put in SGI waiver or TFR corridor for the route to ensure safe flight from hospital to clinic and no other aircraft not involved on the mission would be able to access the airspace.

- Missions Include:
  - VLOS/BVLOS operations to deliver medical supplies from hospital to a local clinic.
  - Pandemic delivery where medical supplies can be sent from roof top to roof top.
- Hazards include:
  - Ground-based transportation network broken.
  - Lack of medical supplies at clinic.
- Types of flight include:
  - During: sUAS with a medical supply on aircraft. Flown under Part 107 or with waiver to higher altitude. May need BVLOS, depending on distance from hospital to clinic.
- UAS to be used:
  - Small UAS with extended payload capacity and endurance.
- Payload includes:
  - Optical camera for video feed back to pilot in command.
  - Medical supplies below airframe.
- Products may include:
  - Real-time: Record of medical device delivered. Recording flight video to and from take-off, landing site at clinic.

<u>Benefits include:</u> CONOP demonstrates how UAS can be used to transport medical supplies during pandemic and if ground logistics prevent deliveries. This would also test small UAS flying in busy airspace with other UAS and manned in the vicinity of flight operations.

### *1.3.3 Use Case #2: Package/medical delivery from large hub to rural community*

CONOP is package delivery from large hub airport to a rural community airport. This CONOP would be to move supplies between two locations that are not on the road network or where the road network prevents the supplies from getting through. The CONOP focuses on essential supplies but is also developed to be used for daily supply route to get community supplies from a main hub.

Focus shows take-off from one site and landing at second location. Package would be delivered, and aircraft would return to main hub airport. Personnel are needed at rural community to meet the aircraft and offload the supplies. Communication occurs between flight team and community team so that once supplies are offloaded then the flight can return to the main hub.

Depending on the endurance of the UAS, this can be flown as a small UAS with Part 107. CONOP includes flying between main hub and community that is off the road network and therefore needs medical supplies, including vaccines flown into the community.

Large UAS needs BVLOS and waivers to support this operation. Also, ground-based tracking and onboard DAA are required to support operations in the NAS. A TFR corridor could be in place if the community is quarantined, and the mission is defined as critical. This corridor ensures that no manned or unmanned aircraft not involved in the mission can enter the airspace.

Payload includes an optical camera to provide real-time feed to GCS and at landing site. Package supplies would be additional payload. Large UAS might be flying in airspace with other possible UAS and manned aviation.

- Missions Include:
  - Large UAS: BVLOS delivers supplies from the large hub airport into a rural community.
  - Small UAS: Part 107 with waivers to support community to community mission.
  - Pandemic delivery sent to a local community to ensure critical supplies are in place to support the day-to-day activities and no drop in transportation network.
- Hazards include:
  - Supply chain issue, land transport limited.
  - Lack of critical supplies at rural community.
- Types of flight include:
  - During: Large UAS flown BVLOS with supplies on the aircraft. Aircraft lands at airport away from the GCS; Needs onboard DAA and sufficient safety systems to fly in NAS
- UAS to be used:
  - Large UAS: Fixed wing or VTOL with BVLOS multi-hour capacity.
  - Small UAS: Long endurance system that is under 55 lbs.
- Payload includes:
  - Optical camera for video feed back to pilot in command.
  - Package for delivery would be included within the aircraft payload capacity.
- Products may include:
  - Real-time: Record of package delivered. Recording flight video to and from take-off, landing site at local community.

<u>Benefits include:</u> This demonstrate how UAS can be used to transport packages during pandemic to ensure continued transportation of goods from main hub to local community. This would also

test large UAS flying in busy airspace with other UAS and manned in the vicinity of flight operations. Would be a test of any DAA equipment, on-board or on ground.

## 1.4 Use Case: Earthquake

### *1.4.1 Summary*

- Use Case 1: Response, sUAS, Post-event, Search And Rescue (SAR) for survivors, VLOS, TIR high quality data critical
- Use Case 2: Response, lUAS, Post-event, Damage extent, lUAS, (E→B)VLOS, Optical/Thermal/LiDAR
- Use Case 3: Response, sUAS and lUAS, Post-event, Tsunami inundation and debris mapping, (E→B)VLOS, Optical/Thermal/LiDAR
- Use Case 4: Response, lUAS, Post-event, Landslide susceptibility mapping, BVLOS, Optical/Thermal/LiDAR

Table 4. Earthquake Use Cases.

| Earthquake use cases | | | | |
|---|---|---|---|---|
| Mission Details | #1 | #2 | #3 | #4 |
| Before/During/After | After | After | After | After |
| Hazard details | Search and Rescue for survivors/building safety/leaks | Damage assessment | Tsunami inundation mapping | Long-term landslide susceptibility mapping |
| Response/Preparedness | Response | Response | Response | Preparedness |
| Type of Flight | Part 107/TFR/Waivers | COA | COA | COA/Waivers |
| Type of LOS | (E➔ B)VLOS | BVLOS | (E ➔ BVLOS) | BVLOS |
| Type of UAS | sUAS and lUAS | lUAS | sUAS and lUAS | lUAS |
| UAS Design | Rotor | Fixed wing | Rotor and Fixed wing | Fixed wing |
| UAS Aircraft | TBD | TBD | TBD | TBD |
| Flight details | Short flights, analyze area, Map rescue missions, structure inspections, Recover monitoring.<br>Flying in and out of buildings.<br>Testing Command and Control (C2) links. | Large scale assessment of damage from EQ [ground subsidence, fault ruptures] | Analysis of inundation caused by tsunami that occurred due to EQ and debris left behind | Repeat pass mapping of susceptible regions to landslide caused from large EQ |

| | | | | |
|---|---|---|---|---|
| Payload | EO/TIR | EO/TIR/LiDAR | EO/TIR/LiDAR | EO/LiDAR |
| Data Collected | Images and Video | Images and video | Images and video | Images and Video |
| Product and Use | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Post-flight: DSM/DEM, Orthomosaics, Geotagged images/video, SfM to capture extent of ground failures, LiDAR point clouds and 3D models | Post-flight: DSM/DEM, Orthomosaics, Geotagged images, LiDAR point clouds and 3D models | Post-flight: DSM/DEM, Orthomosaics, Geotagged images/video, LiDAR point clouds and 3D models |
| Notes | Real-time data back to GCS and shared with decision manager. | Derived maps of damage, DSM to show any land subsidence | Maps of damage, DSM to show extent of tsunami impact | Maps of the local landscape and dDSM maps |

### *1.4.2 Use Case #1: Thermal/EO for Search and Rescue as well as infrastructure safety*

CONOP operates as soon as a SAR effort is deemed necessary. Mission includes SAR operations with Electro-Optical (EO) and thermal cameras search for survivors in impacted zones. Thermal and optical data are collected to support infrastructure safety analysis.

Small UAS are used, given their ability for short term campaigns, and in VTOL form, ability to provide flights from small take-off and landing spaces. Also, the CONOP includes a small UAS flying in and out of buildings, both undamaged and damaged. The CONOP allows an examination of C2 links for navigation as well as the data flow to the GCS and command center.

Additionally, surveying for potential gas leaks would be extremely valuable to support the disaster response efforts. After the 2016 M7.1 Iniskin earthquake, natural gas leaks on the Kenai Peninsula, Alaska, did considerable damage. UAS employ gas sensors on-board along with EO and TIR to support response. Selection of sites is chosen by those most impacted from the earthquake. Large UAS provide support for regional impact assessment and analysis while small UAS supports neighborhood/community assessment.

Focus of the mission is on streaming back optical and thermal data to the GCS and on to the incident command center as well as those emergency managers performing ground search and rescue.

Another focus is on collecting optical and thermal data to rapidly develop 3D models of the infrastructure to support those in the incident command team to assess the safety of the structures.

Large UAS need BVLOS operations and waivers or COAs to support operations. Ground based tracking and onboard DAA to support mission, as the VTOL small UAS may not have onboard DAA.

Payloads include optical and thermal cameras to provide real-time feed to GCS and where possible gas sensors to assess leaks from local utilities.

- Missions Include:
  - VLOS to BVLOS SAR operations straight after earthquake and assess building safety
  - SAR for survivors and initial damage assessment of earthquake
  - sUAS to fly in and out of buildings, testing data stream and GPS to IMU based C2
- Hazards include:
  - Large Earthquake
  - Collapse and/or at-risk infrastructure
  - Population at-risk/lost
  - Potential utility gas leaks with second-order hazards
- Types of flight include:
  - Post-event: Short sUAS flights to perform SAR and assess buildings impacted by earthquake; Long endurance lUAS flights for regional analysis.
- UAS to be used:
  - Small UAS: VTOL with rapid flight time, quick turnaround, ability to move to new take- off sites quickly, payload capacity for EO/TIR
  - Large UAS: Fast fixed wing to support regional mapping for possible gas leaks
- Payload includes:

    - Optical and thermal infrared cameras with additional gas sensor to support assessment for gas leaks
- Products may include:
    - Real-time: Images and video to GCS and onto incident command
    - Post-processed: Geotagged Imagery, DSM/DEM models, mapped hazardous zones in GIS data, 3D model of impacted area, and orthomosaic maps

Benefits include: Operations to show how small UAS can be used for SAR and provide real-time data back to decision maker. Demonstrate SGI process. Show how multiple UAS may be flown at once. Demonstrate how small UAS can navigate through buildings and ensure command and control communications throughout as well as stream data back to GCS.

### *1.4.3 Use Case #2: Damage assessment of impact to infrastructure for recovery efforts and understand landscape to evaluate impact from future aftershocks*

CONOP is to collect thermal and optical imagery and video of the full extent of the damage caused by the earthquake. This would occur once use case #1 would have completed SAR and initial building surveys. Use case #2 would be to support recovery operations. Ideally, this CONOP starts while use case #1 is still being completed.

CONOPs are combined so that the collected data for search and rescue could be used by incident command team to assess damage from earthquake to speed and optimize up the recovery efforts for those at-risk zones. Note that in the first few hours after an earthquake it can be exceptionally hard to know where to send resources such as search and rescue. Areas or buildings that do not have communication may be ignored because no one is calling in. For a subduction zone scale earthquake with damage in many different towns, allocating SAR resources is very hard. A large, fixed wing UAS in the initial hours helps to determine where to deploy use case #1.

A focused mission maps building damage using optical photogrammetric methods. Including LiDAR data in a CONOP supports decision makers in assessing the movement of the fault by mapping the precise ground displacement to help identify the actual fault(s) that ruptured. Knowing the exact ground offsets during the earthquake allows the faults to be mapped quickly to improve the assessment of risk posed by subsequent aftershocks. Aftershocks can cause real damage and casualties in some settings, even weeks or months after the earthquake. In the 2018 Anchorage quake impacts occurred nearly two months after the M7.1 main quake.

Focus is to collect data to map building damage and areas at risk while adding high precision LiDAR data of landscape to understand potential impact of future aftershocks. Optical data would allow assessment of required recovery effort and understand the full extent of the earthquake impact on the infrastructure and local community. LiDAR data supports precise mapping of ground displacement, evaluating fault ruptures, and ground offsets.

Payloads include optical and thermal infrared (TIR) sensors and where possible LiDAR equipment. Post flight products include orthomosaic maps of the flooding damage as well as digital surface models of the flown flight area. If possible, LiDAR sensor could capture high resolution data to map the landscape.

- Missions Include:
    - BVLOS operations to map extent of earthquake impact

- Damage assessment of infrastructure and landscape from earthquake

- Hazards include:
  - Large Earthquake
  - Major damage to infrastructure and recovery assessment needed
  - Need knowledge on ground ruptures for impact from aftershocks
- Types of flight include:
  - Post-event: Map extent of damage, evaluate fault locations, land subsidence, assessment of recovery operations needed
- UAS to be used:
  - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR
- Payload includes:
  - Optical and TIR cameras
  - LiDAR where possible [depends on payload capacity of UAS]
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping earthquake damage to landscape and infrastructure as GIS data, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: CONOP tests teams' ability to collect optical and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and observers' communications with pilot in command. This would a post-event operation to build assessment maps of the full extent of the damage.

### *1.4.4 Use Case #3: Tsunami inundation mapping*

CONOP is to map the impact of an earthquake generated tsunami on the local landscape. These tsunamis can have a devasting impact on the nearby landscape following an earthquake as well as impacts at locations much further away from the earthquake epicenter.

A very significant tsunami occurred in Alaska following the 1964 9.2 magnitude earthquake. Local tsunamis formed from landslides as well as a regional tsunami across the Pacific. The surge wave caused $10M in Whitter, Alaska and reached > 30m above low tide. This was > 70 km from the epicenter. Also, significant surges impact Valdez (9.1 m) and Kodiak (6.1 m). An important note is that devastating local tsunamis spanned from Prince William Sound to Kodiak. That is more than 600 km and thousands of kilometers of coastline.

Therefore, large UAS are needed along with small UAS. The large UAS will fly around the region impacted by the tsunamis to get a picture of the damage while the small UAS are flown in local communities to map the inundation.

Coordination is needed to rapidly respond and get large UAS data back to the incident command and to stream any small UAS data. A large UAS flies pre-program routes of anticipated inundation and/or a developed mission based off the likely inundation using a full-scale modeling scenario with tools like tsunami.alaska.edu.

Sensors onboard include EO/Thermal infrared/LiDAR. Large UAS fly BVLOS and need DAA systems on-board and/or ground-based tracking. Small UAS fly under Part 107 with VLOS or use TFR/COA/SGI/Part 107 waivers to support operations if other air assets in play

- Missions Include:
  - Large UAS: Regional BVLOS operations to map full extent of inundation
  - Small UAS: Local VLOS to BVLOS missions per community
- Hazards include:
  - Large Earthquake causes local and regional tsunamis
  - Tsunamis across large region and significant impact to communities
  - Need to map inundation and assess susceptibility of future landslides ➔ tsunamis
- Types of flight include:
  - Post event: Map extent of inundation both regionally and per community
  - Large UAS under BVLOS with Waivers, Small UAS: Part 107 and/or Waivers
- UAS to be used:
  - Large UAS: Fast fixed wing with long endurance for regional mapping with EO/LiDAR
  - Small UAS: VTOL and short duration to map inundation extent per community
- Payload includes:
  - Optical and IR cameras, with LiDAR where possible on large UAS or sUAS with higher payload capacity
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping tsunami inundation damage to landscape and infrastructure as GIS data, and orthomosaic maps.

Benefits include: CONOP tests teams' ability to collect EO/LiDAR data over a large area and coordinate a large UAS BVLOS mission while also supporting local small UAS operations. CONOP would evaluate how missions respond to other UAS and observers' communications with pilot in command, especially in local communities. This would a post-event operation to build assessment maps of the full extent of the tsunami inundation.

#### *1.4.5 Use Case #4: Long term landslide susceptibility mapping*

Following an earthquake and subsequent infrastructure and landscape damage, there is the potential for future landslides in susceptible locations that can lead to further damage. Therefore, this CONOP focuses on routine operations with a large or small UAS to continue to map susceptible zones that could lead to significant landslides and a new natural disaster response. Hillsides in urban areas may be small but pose direct threat to a neighborhood. Whereas unstable mountainsides in remote areas may be much larger in size and may be tied to secondary hazards such as landslide tsunamis (see the Barry Arm threat to Wittier, Alaska).

CONOP team responds on a routine basis, such as weekly or monthly, depending on the need and frequency of observations. Large UAS covers regional areas for mapping while small UAS gains closer access to areas of interest and responds quicker if a susceptible zone was now a risk. Subsequent landslide hazard is likely to be much higher during periods of inclement weather. Heavy rainfall is a primary trigger for any type of landslide. These are precisely the times that are difficult to fly where a UAS with VFR capability can support decision making process when helicopters or manned aircraft cannot fly.

Large UAS flies under BVLOS and waivers to fly in the NAS, a COA also used as the aircraft would be the same for each mission and covering the same region of interest. Small UAS are used to access those sites at highest risk and flown under Part 107 with waivers if needed for operations not under Part 107 regulations. EO/LiDAR sensors on-board. Products would include building DEM/DSM from each flight and then examining the differences to build a differential DEM/DSM or derived dDEM or dDSM. Decision makers could then assess likelihood for failure and increase or reduce frequency of observations.

- Missions Include:
  - Large UAS: Regional BVLOS operations, Routine data collection
  - Small UAS: Local VLOS operations for areas of greatest risk for hazard
- Hazards include:
  - Landslides from unstable landscape following Earthquake
  - Possible future disaster response
- Types of flight include:
  - Post event: Scheduled missions, mapping local landscape, Providing EO and LiDAR data to build DEM/DSM maps and then dDEM/DSM maps to assess hazard
- UAS to be used:
  - Large UAS: Fixed wing with long endurance for regional mapping with EO/LiDAR
  - Small UAS: VTOL and short duration to map most at-risk areas
- Payload includes:
  - EO/TIR. LiDAR, where possible depending on UAS capacity and payload limits
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models and orthomosaic maps
  - Differential DEM/DSM models of landscape
  - Susceptibility maps from dDEM/dDSM data

Benefits include: CONOP would assess how team could provide continued support for post-event disaster response and how to increase or decrease frequency of missions depending on decision support needs. Evaluation of large and/or small UAS flying together. Post-Processed products of dDEM/dDSM.

## 1.5 Use Case: Volcano

### *1.5.1 Summary*

- Use Case 1: Prepare, lUAS, EO/TIR/Gas/LiDAR, BVLOS, Summit map, like occupied/Blackswift
- Use Case 2: Response, sUAS, Ongoing, lava flow/SAR, VLOS, Hawaii 2018 example, EO/TIR/LiDAR
- Use Case 3: Response, lUAS, Ongoing, Gas/ash cloud, BVLOS/TFR, like occupied/Blackswift
- Use Case 4: Response, sUAS/lUAS, Post-event, Damage extent, (E→B)VLOS, EO/TIR/LiDAR

Table 5. Volcano Use Cases.

| Volcano use cases | | | | |
|---|---|---|---|---|
| Mission Details | #1 | #2 | #3 | #4 |
| Before/During/After | Before | During | During | Post |
| Hazard details | Volcano activity analysis prior to eruption | Lava flow mapping [like Hawaii 2018] | Gas and ash cloud sampling | Damage assessment and eruption analysis |
| Response/Preparedness | Preparedness | Response | Response | Response |
| Type of Flight | COA/Waivers | Part 107 and Waivers | TFR/COA | COA/waivers |
| Type of LOS | BVLOS | (E→B)VLOS | BVLOS | BVLOS |
| Type of UAS | lUAS | sUAS | S(l)UAS | lUAS |
| UAS Design | Fixed wing | Rotor or Fixed Wing | Rotor or Fixed wing | Fixed wing |
| UAS Aircraft | TBD | TBD | TBD | TBD |
| Flight details | Operations to map area of activity when volcano at elevated alert | Mapping active lava flows that can impact community | Sampling eruption plumes | Map total eruption area |
| Payload | EO/TIR/Ash and Gas sensor/LiDAR | EO/TIR/LiDAR | Ash and Gas sensor | EO/TIR/LiDAR |
| Data Collected | Imagery, Video, and time series of | Imagery, Video, and time series of samples | Imagery, Video, and time series of samples | Imagery and Video |

| | | | | |
|---|---|---|---|---|
| | samples | | | |
| Product and Use | Thermal and EO map of active area, 3D profiles of ash and gas concentrations | Thermal and EO map of active flows, Speed of lava | 3D profile of ash and gas concentrations | Thermal and EO map of eruptive extent |
| Notes | Data processed after flight and provided to the local volcano observatory to accompany any other ground-based observations | Data streamed real-time to decision makers as well as develop post-produced map of flows | sUAS if can reach eruptive site. lUAS if long distance. Build data on eruptive gas and ash amounts | Derived maps of damage, DSM to understand eruptive volume |

### 1.5.2 *Use Case #1:* ***Assessment of precursor eruptive behavior***

The CONOP supports a preparedness mission to collect optical and thermal data of potentially eruptive volcanoes as well as volcanic gas and ash concentrations to support a local volcano observatory. These operations currently are performed by manned aviation flights, either in fixed wing aircraft or helicopters and volcano scientists with the optical/thermal/gas/ash sensors onboard

A volcano observatory analyzes geophysical data, such as seismic and infrasound signals, to assess if a volcano activity levels have reached above their typical background levels. If the alert level of the volcano is raised, then decisions are made by the observatory on a need for any airborne observations and so they may perform manned flights to collect data from the location of enhanced ground signals.

This CONOP performs an UAS equivalent of these manned missions for the local observatory. Focus is to collect optical and thermal data of the unrest regions of a volcano and when needed measurements of the volcanic gases and ash being emitted. This would be on a volcano-by-volcano basis and so the CONOP developed in coordination with a local volcano observatory. BVLOS operations are needed with possible waivers and COA.

Large UAS needed given distance to volcano location. Onboard DAA and/or ground-based tracking capabilities required for safe integration into the NAS.

The CONOP adds in summit/active region flights with a small UAS where the flight time is close to the active region and able to map the area of interest with a small UAS and VLOS operations.

Payloads include EO and TIR sensors along with capability to measure gas and ash concentrations. If possible, LiDAR sensor could capture high resolution data to map the landscape. Products include optical and thermal orthomosaic maps of the volcano along with 3D profiles of the gas and ash concentrations. Data and products are provided to the local volcano observatory to support their decision-making process on volcanoes activity levels.

- Missions Include:
  - BVLOS operations to reach volcanic activity area with large UAS
  - Coupled with local VLOS mission using small UAS
  - Flights to active region showing heighted level. Possible waivers and or COA needed
- Hazards include:
  - Heighted activity levels and alert levels at volcano
- Types of flight include:
  - Pre-event: Map summit area with optical and thermal cameras
- UAS to be used:
  - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR
  - Small UAS: VTOL at the active region to accompany the regional large UAS flights
- Payload includes:
  - Optical and IR cameras as well as gas/ash sensors
  - LiDAR where possible [depends on payload capacity of UAS]
- Products may include:
  - Real-time: Images and video to GCS for flight operations

  - Post-processed: Provided to local volcano observatory, Geotagged Imagery, 3D profiles of gas and ash concentrations, DSM/DEM models, mapped summit area in optical and thermal format as GIS data, 3D model of impacted area, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: Large UAS operations over a volcanic region with supplemental small UAS for local flights over the active site, test capabilities to provide equivalent operations to that from manned flights. DAA test for UAS operations in NAS. Flown under COA/SGI so it is possible to evaluate process to set up as preparedness mission rather than response mission. Learn to develop CONOP so that missions could be used to analyze multiple volcanoes from one launch site, such as Cook Inlet volcanic chain in Alaska from Anchorage or Kenai Peninsula. Testing of BVLOS operations over large distance where IFR might occur given weather conditions. Flights with large UAS could fly where fixed wing manned or helicopter flights may be limited by weather conditions.

### *1.5.3 Use Case #2: Lava flow mapping*

CONOP is to support a team to map the eruptive products from an active volcano including lava flows. Focus is on rapid response missions and short flights to collect optical and thermal imagery and video of the lava flows. These can be rapidly changing eruptive products and so need multiple flights to map the flows and where possible evaluate their flow speed.

This latter product supports volcano observatory to determine future flow trajectory and decision-making process. Focus is to collect optical and thermal data of the eruptive products from the volcano. EVLOS to BVLOS operations are needed with possible waivers and COA. A TFR may be in place given the volcanic hazard and the need to mitigate other non-response aircraft from accessing airspace. Possible nighttime and over people may be needed given level of activity.

Note: USGS National UAS Project Office, the USGS Cascades Volcano Center, and Department of the Interior (DOI) Office of Aviation Services (OAS) supported Hawaii Volcano Observatory monitored the volcanic activity using thermal and optical video imagery, gas sensing on board the UAS, and still-frame imagery provided data for situational awareness, three-dimensional mapping, flow estimations and extents, and gas emission measurements.

Payloads include EO and TIR sensors. If possible, LiDAR sensor capture high resolution data to map the landscape. Products include orthomosaic maps of the volcano. Data and products are provided to the local volcano observatory to support their decision-making process on volcanoes activity levels. The team evaluates how to transfer raw imagery and derived products to the end user.

- Missions Include:
  - VLOS ➔ BVLOS operations to map eruptive lava flows from active volcano
  - Waivers and or COA needed. Main need rapid response SGI. TFR in place.
  - Mapping lava flows to assess progression and risk to infrastructure and population
- Hazards include:
  - Lava flows from consistent volcanic activity
  - Impact to local community and infrastructure
- Types of flight include:

  - During: Rapid response flights to map lava flows with optical and thermal cameras
- UAS to be used:
  - Small UAS: Fixed wing/VTOL with short endurance for rapid turnaround on flights
- Payload includes:
  - Optical and thermal infrared cameras
  - Ash and gas sampling equipment [$CO_2$/$SO_2$/$H_2S$] as well as T/P/RH atmos. sensors
  - LiDAR where possible [depends on payload capacity of UAS]
- Products may include:
  - Real-time: Images and video to GCS and onto incident command
  - Post-processed: Geotagged Imagery, DSM/DEM models, mapped eruptive area in optical and thermal format as GIS data, 3D model of impacted area, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.
  - Note: For Kilauea response in 2018, high-res. data provided for emergency responders, including analysis of lava-surrounded communities. Live video feeds of lava flow conditions/paths to the EOC in support of emergency evacuation efforts.

Benefits include: Practice with small UAS operations. Test of real-time data streams back to GCS and incident command. Rapid response missions over short time scales. Flying of multiple sUAS in same vicinity. Flying under SGI and/or with TFR in place. Maybe non-mission aircraft flying around outside the TFR such as helicopters and other manned aircraft. May require flight time to traverse to the hazardous environment if only VLOS flights.

#### *1.5.4 Use Case #3: Gas and ash cloud sampling*

CONOP is to sample (1) eruptive plume at active vent or volcano summit, and (2) downwind gas and/or ash clouds to assess potential impact to population, infrastructure, and transportation networks. Sampling eruption plume and downwind cloud could be completed with one mission, depending on the endurance of the UAS. Operations are currently performed by manned aviation flights, either in fixed wing or helicopters, with the optical/thermal/gas/ash sensors onboard. UAS fly through these plumes and clouds without putting personnel at-risk, which are not usually done by manned flights as risk is too high.

Focus is to collect optical and thermal data of the plumes and ash clouds and to conduct measurements of the volcanic gases and ash emitted. BVLOS operations are needed with possible waivers and COAs. Large UAS are needed given distance to volcano location. Onboard DAA is useful and/or ground-based tracking capabilities are employed. Note that TFR is likely in place over the summit. PIREPs from manned flights or ground observations support the mission team to assess area to map for downwind clouds. Summit mission will follow specific route as well as some manual operations to sample the developing plume. Downwind cloud mission will require manual operations as the cloud disperses and is transported by the atmospheric winds.

Payloads include EO and TIR sensors along with capability to measure gas and ash concentrations. Products include optical and thermal orthomosaic maps of the volcano along with 3D profiles of the gas and ash concentrations. Data and products are provided to the local volcano observatory to support their decision-making process on volcano alert level. Data also are sent to incident command/emergency command center.

- Missions Include:

  - EVLOS/BVLOS to sample gas and/or ash from volcanic plumes and downwind clouds
  - Waivers and or COA needed. Main need rapid response SGI. TFR in place at summit.
  - Continued sampling of plume from active region as well sampling of downwind clouds
- Hazards include:
  - Volcanic gas and/or plumes and clouds emitted from volcano
  - Population centers and infrastructure at-risk
  - Downwind impact to aviation community and local communities
- Types of flight include:
  - During: Measure ash & gas concentrations. Resample based on data collected
  - TFR/SGI in place as active volcano and do not want other aircraft in the vicinity
  - Flight into and out of TFR, as this would only over summit/active region
  - Flight team need COA in place for operations
- UAS to be used:
  - Fixed wing/VTOL large UAS with long endurance and payload capacity
- Payload includes:
  - Optical and thermal infrared cameras
  - Ash and gas sampling equipment [$CO_2$/$SO_2$/$H_2S$] as well as T/P/RH atmos. sensors
- Products may include:
  - Real-time: Images and video to GCS and onto incident command
  - Post-processed: Geotagged Imagery, DSM/DEM, mapped eruptive area in optical and thermal format as GIS data, 3D models of impacted area, and orthomosaic maps

Benefits include: Equivalent flights to manned aircraft to assess UAS capacity to support disaster response. BVLOS operations and possible SGI/COA/TFR. Depending on flight location, the operations IFR only. Real-time and/or post processing of plume/clouds for decision making at incident command and/or volcano observatory. Both pre-defined routes and manual operations tested. Also assess how unmanned mission critical aircraft operate to support decision making while non-mission critical aircraft are within vicinity. Note that aircraft may need to take-off and land at locations outside a TFR so SGI waiver would be needed and/or other permissions for airspace.

### *1.5.5 Use Case #4: Damage assessment and eruption analysis*

CONOP is the mission after the eruption has ended. UAS capture a significant amount of data after the event is over, depending on the sensor suite onboard the aircraft. Coordination with the volcano observatory on the critical data needed is essential to optimize the mission data collection. UAS collect optical and thermal imagery and video of damage caused volcanic eruption and its deposits. They also collect data to map spatial extent of eruptive products and to support recovery.

Payloads include EO and TIR sensors. Post flight products include orthomosaic maps of the damage from the volcano’s eruptive products and digital surface models of the flown flight area. If possible, LiDAR sensor could capture high resolution data to map the landscape. Additional products include 3D models of the eruptive products to support volcano observatory’s determination of total eruptive volume. Note: Mission would need pre-eruption DEM/DSM collected by the same sensor or at least the same GSD.

- Missions Include:
    - BVLOS operations to map extent of volcanic eruption
    - Possible waivers and or COA needed
    - Assess impact to landscape and infrastructure
    - Provide data to support volcano observatory to understand eruption
- Hazards include:
    - Volcanic eruption with significant ground eruptive products
    - Major damage to infrastructure
    - Recovery assessment needed
- Types of flight include:
    - Post-event: Large-scale mapping with optical and thermal cameras
- UAS to be used:
    - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR
- Payload includes:
    - Optical and IR cameras
    - LiDAR where possible [depends on payload capacity of UAS]
- Products may include:
    - Post-processed: Geotagged Imagery, DSM/DEM models, mapped eruptive area in optical and thermal format as GIS data, 3D model of impacted area, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: CONOP tests teams' ability to collect optical and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and observers' communications with pilot in command. This would a post-event operation to build assessment maps of the full extent of the damage.

## 1.6 Use Case: Hurricane

### *1.6.1 Summary*

- Use Case 1: Response, sUAS/lUAS, Post-event, SAR for survivors, (B)VLOS, TIR high quality data is critical
- Use Case 2: Response, lUAS, Post-event, Damage extent, (E→B)VLOS, EO/TIR/LiDAR, no real-time

Table 6. Hurricane Use Cases.

| Hurricane use cases | | |
|---|---|---|
| Mission Details | #1 | #2 |
| Before/During/After | After | After |
| Hazard details | Search and Rescue for survivors/building safety | Damage assessment |
| Response/Preparedness | Response | Response |
| Type of Flight | Part 107/TFR/Waivers | COA |
| Type of LOS | (E→ B)VLOS | BVLOS |
| Type of UAS | sUAS | lUAS |
| UAS Design | Rotor | Fixed wing |
| UAS Aircraft | TBD | TBD |
| Flight details | Short flights, analyze area, Flying in and out of buildings. Testing C2 links. | Large scale assessment of damage from Hurricane |
| Payload | EO/TIR | EO/TIR/LiDAR |
| Data Collected | Images and Video | Images and video |
| Product and Use | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Post-flight: DSM/DEM, Orthomosaics, Geotagged images/video |
| Notes | Real-time data back to GCS and shared with decision manager. | Derived maps of damage |

### 1.6.2 ***Use Case #1: Thermal/EO for Search and Rescue as well as infrastructure safety***

CONOP is to operate as soon as a SAR effort is deemed necessary.

(1) SAR operations with optical and thermal cameras search for survivors in impacted zones
(2) Thermal and optical data are collected to support damage assessment.

First small UAS is used given ability for short term campaigns and in VTOL form provides flights from small take-off and landing spaces. Also, a second small UAS is flying in and out of buildings. Mission will examine C2 links for navigation and data being streamed back to command center.

(1) Focus is on streaming back optical and thermal data to the GCS and onto the Incident Command Center as well as air and ground response units performing SAR missions; (2) Focus is also on collecting optical and thermal data to rapidly develop 3D models of the infrastructure to support damage assessment by Incident Command Center and response authorities.

Post event analysis and data collection will support confirmation and evaluation of reported roadway flooding impacts, including determining if the roadway would be safe when the water receded or had been damaged significantly enough to merit continued closure/rehab, and (2) evaluation of traffic impacts along detour routes set up along minor and secondary roads through rural communities. Other items to examine could include but are not limited to dam spillways and similar structures that were dealing with the runoff from all the rain, including minor structures like creek and pond levees.

BVLOS and Part 107 or SGI waivers may be needed to support operations for sUAS if ariel coverage is extensive. Ground based tracking DAA to support BVLOS, as the VTOL sUAS may not have onboard DAA.

Payloads include optical and thermal cameras to provide real-time feed to GCS.

- Missions Include:
  - VLOS to BVLOS SAR operations straight after hurricane and assess building safety.
  - SAR for survivors and initial damage assessment of hurricane.
  - SUAS to fly in and out of buildings, testing data stream and GPS to IMU based C2.
- Hazards include:
  - Major Hurricane that makes landfall.
  - Major damage to infrastructure.
  - Recovery assessment needed.
  - Other response aircraft.
  - Non-response aircraft.
  - Towers and powerlines.
- Types of flight include:
  - Post-event: short flights to perform SAR and assess buildings impacted by hurricane.
- UAS to be used:
  - Small UAS #1: VTOL with rapid flight time, quick turnaround, ability to move to new take-off sites quickly, payload capacity for EO/TIR.
  - Small UAS #2: VTOL and ability to fly into and out of structures to assess damage/SAR.
- Payload includes:

    - Optical and thermal infrared cameras.
- Products may include:
    - Real-time: Images and video to GCS and onto incident command.
    - Post-processed: Geotagged Imagery, DSM/DEM models, mapped hazardous zones in GIS data, 3D model of impacted area, and orthomosaic maps.

Benefits include: Operations to show how small UAS can be used for SAR and provide real-time data back to decision makers and response teams. Demonstrate SGI process. Show how multiple UAS can support initial SAR and damage assessment during post-hurricane event. Test C2 capabilities for flights internally within structures.

#### *1.6.3 Use Case #2: Damage assessment of impact to infrastructure for recovery efforts*

CONOP is to collect thermal and optical imagery and video of the full extent of the damage caused by the hurricane. This occurs after use case #1 has completed SAR and initial building surveys. Use case #2 is designed to support recovery operations. Focus is to collect data to map building damage and areas at risk for continued collapse. Data allows assessment of required recovery effort and understanding of the full extent of the hurricane's impact on the infrastructure.

Large UAS are flown at higher altitude to provide full assessment of damage. Small UAS #1 flies at lower altitude and completes directed flights from large UAS data to examine specific areas. Small UAS #2 provides mission team the ability to get in close and examine safety of structures. Second small UAS flown is by first responders/damage assessment teams on ground. Large UAS and first small UAS are flown from command center or main launch site. Payloads include EO and TIR sensors. Post flight products include orthomosaic maps of the hurricane damage as well as digital surface models of the flown flight area. If possible, LiDAR sensor will capture high resolution data to map the landscape.

- Missions Include:
    - BVLOS operations to map extent of hurricane impact.
    - Damage assessment of infrastructure and landscape from hurricane.
- Hazards include:
    - Major Hurricane that makes landfall.
    - Major damage to infrastructure.
    - Recovery assessment needed.
    - Other response aircraft.
    - Non-response aircraft.
    - Towers and powerlines.
- Types of flight include:
    - Post-event: Map extent of damage, evaluate at-risk infrastructure, assessment of recovery operations needed.
- UAS to be used:
    - Large UAS: Long endurance flights over the damaged area.
    - Small UAS #1: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR.
    - Small UAS #2: fast, nimble, close in assessment of building safety for recovery efforts.
- Payload includes:

    - Optical and thermal infrared cameras.
    - LiDAR where possible [depends on payload capacity of UAS].
- Products may include:
    - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping damage from hurricane to landscape and infrastructure as GIS data, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

<u>Benefits include:</u> CONOP tests teams' ability to collect visible and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and communication among flight crewmembers. Post-event operation will build assessment maps of the full extent of the damage. Long endurance small UAS and fast nimble small UAS are flown at the same time as well as large UAS is flown above both. Automated flight routes as well as manual operations collect targeted data to support recovery efforts and damage assessment.

## 1.7 Use Case: Flooding

### *1.7.1 Summary*

- Use Case 1: Response, s(l)UAS, Ongoing/Post-event, SAR for survivors, (B)VLOS, TIR high quality data is critical
- Use Case 2: Response, s(l)UAS, Ongoing, Flood extent and change, (B)VLOS, TIR high quality data is critical
- Use Case 3: Response, lUAS, Post-event, Damage extent, (E→B)VLOS, EO/TIR/LiDAR, no real-time

Table 7. Flooding Use Cases.

| Flooding use cases | | | |
|---|---|---|---|
| Mission Details | #1 | #2 | #3 |
| Before/During/After | During | During | After |
| Hazard details | Search and Rescue for survivors | Flood extent and change | Damage assessment |
| Response/Preparedness | Response | Response | Response |
| Type of Flight | Part 107/TFR/Waivers | TFR/waivers | COA |
| Type of LOS | (E→ B)VLOS | (E→ B)VLOS | BVLOS |
| Type of UAS | sUAS | lUAS | lUAS |
| UAS Design | Rotor | Fixed Wing | Fixed wing |
| UAS Aircraft | TBD | TBD | TBD |
| Flight details | Short flights, analyze area, Flying in and out of buildings. Testing C2 links. | Long flights, mapping over flooding extent | Large scale assessment of damage from flooding |
| Payload | EO/TIR | EO/TIR/LiDAR | EO/TIR/LiDAR |
| Data Collected | Images and Video | Images and Video | Images and video |

| | | | |
|---|---|---|---|
| Product and Use | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Real-time: Geotagged images/video Post-flight: DSM/DEM, Orthomosaics | Post-flight: DSM/DEM, Orthomosaics, Geotagged images/video |
| Notes | Real-time data back to GCS and shared with decision manager | Real-time data back to GCS and shared with decision manager. Post flight: maps of flooded area | Derived maps of damage |

### 1.7.2 *Use Case #1: Thermal/EO for search and rescue as well as infrastructure safety*

CONOP is to operate as soon as a SAR effort is deemed necessary. Operations with optical and thermal cameras search for survivors in impacted zones. Thermal and visible data are collected to support infrastructure safety analysis. Small UAS are used for short term campaigns and VTOL will provide flights from small take-off and landing zones. There will be small UAS flying in and out of buildings. The mission examines command and control links for navigation as well as data being streamed back to GCS and command center.

Note that initial SAR during the flooding is primarily supporting those in distress. If there is anyone inside the structures, it's a rescue event. The goal of the thermal/EO search is finding individuals in extremis situations, determine who has contacted emergency managers (EM) and those who cannot make contact. This mission occurs during ongoing flood and is different from post-event assessment (use case #2). Focus is on streaming back optical and thermal data to the GCS and onto the incident command center as well air and ground response units performing SAR missions. Focus is on collecting data to rapidly develop models of infrastructures to support the Incident Command Center response. BVLOS and waivers are needed to support operations. Ground based tracking and onboard DAA will support BVLOS, as the VTOL small UAS may not have onboard DAA. Payloads include optical and thermal cameras to provide real-time feed to GCS.

- Missions Include:
  - VLOS to BVLOS operations to perform SAR operations straight after flooding starts..
  - SAR for survivors and initial damage assessment of flooding.
  - sUAS to fly in and out of buildings, testing data stream and GPS to IMU based C2.
- Hazards include:
  - Significant flooding event.
  - Population at-risk/lost.
  - Towers and powerlines.
  - Rapidly changing environment.
- Types of flight include:
  - During: short flights to perform SAR and assess buildings impacted by flooding.
- UAS to be used:
  - Small UAS: VTOL with rapid flight time, quick turnaround, ability to move to new take- off sites quickly, payload capacity for EO/TIR.
- Payload includes:
  - Optical and thermal cameras.
- Products may include:
  - Real-time: Images and video to GCS and onto incident command.
  - Post-processed: Geotagged Imagery, DSM/DEM, mapped hazards zones in GIS data, 3D model of impacted area, and orthomosaic maps.

<u>Benefits include:</u> Operations will show how small UAS can be used for SAR and provide real-time data back to decision makers and response teams. This mission demonstrates SGI process. CONOP shows how multiple UAS can support initial SAR response in a flooding event, tests command-and-control capabilities when flying in and out of buildings, and tests how small UAS can be used to track location of survivors to support those on the ground to travel to their locations. Data is used

by incident command to then communicate with ground teams or ground teams get direct feed and could even fly small UAS from the boat over to at-risk locations.

### *1.7.3 Use Case #2: Flood extent assessment and change*

CONOP represents support flights to map out the flooded area as well as the changing landscape from an ongoing flooding. Missions collect optical and thermal data of flooding and how information changes to support assessment of future impact to local communities and infrastructure. Large UAS support long endurance flights where the aircraft could be flown to map the full extent and be sent to targeted areas where rapid changes to the flooded areas are occurring

UAS focus on streaming back optical and thermal data to the GCS and onto the incident command center as well as those EMs performing ground SAR. They need BVLOS and waivers to support operations. Also ground based tracking and onboard DAA is needed to support BVLOS, as the VTOL small UAS may not have onboard DAA. Note for this mission is not to interfere with any on-going SAR response, so use case #1 and #2 could run in parallel and assess capabilities of two teams and ability to separate airspace. Payload would include optical and thermal cameras to provide real-time feed to GCS. If possible, LiDAR sensor could capture high resolution data to map the landscape.

- Missions Include:
  - VLOS to BVLOS to perform assess changing environment as flooding continues.
  - Collect optical and thermal data of flooded area over multiple flights to support decision making on speed at which flooding is occurring.
- Hazards include:
  - Significant flooding event.
  - Population at-risk/lost.
  - Rapidly changing environment.
  - Towers and powerlines.
  - Other manned and unmanned response aircraft.
  - Non-mission aircraft in airspace.
- Types of flight include:
  - During: Long endurance flights to assess extent of environment for ongoing flooding.
- UAS to be used:
  - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR.
- Payload includes:
  - Optical and IR cameras.
  - LiDAR where possible [depends on payload capacity of UAS].
- Products may include:
  - Real-time: Images and video to GCS, incident command and EM's supporting response.
  - Post-processed: Geotagged Imagery, DSM/DEM, Hazard zones in GIS data, 3D model of impacted area, and orthomosaic maps. LiDAR point cloud/3D models.

<u>Benefits include:</u> Real-time mapping of flood extent. Data streamed back from large UAS to GCS and Incident Command Center. Capability to determine flooding extent as the disaster is still ongoing. Assessment of how this use case can run in parallel with #1 where maybe need for airspace

deconfliction. Test small and large UAS operating at the same time. Also, test two use cases running at the same time so could lead to airspace deconfliction assessment. Evaluate how flight teams communicate with decision makers and fly both planned routes as well as manual operations where they can navigate to the at-risk locations or where more observational data is needed.

#### 1.7.4 Use Case #3: Damage assessment of impact to infrastructure

CONOP is to collect thermal and visible imagery and video of the full extent of the damage caused by the flooding. This use case occurs once use case #1 has completed SAR and can run in parallel with use case #2 supporting SAR operations. Focus is to collect data to map building damage and areas at risk. Data allows assessment of required recovery effort and understand the full extent of the flooding impact on the infrastructure and local community. Payloads include EO and TIR sensors. Post flight products would include orthomosaic maps of the flooding damage as well as digital surface models of the flown flight area. If possible, LiDAR sensor could capture high resolution data to map the landscape.

- Missions Include:
  - BVLOS operations to map extent of flooding impact.
  - Damage assessment of infrastructure and landscape from flooding.
- Hazards include:
  - Significant flooding event.
  - Population at-risk/lost.
  - Rapidly changing environment.
  - Towers and powerlines.
  - Other response aircraft.
  - Non-mission aircraft in airspace.
- Types of flight include:
  - Post-event: Map extent of damage, evaluate at-risk infrastructure, assessment of recovery operations needed.
- UAS to be used:
  - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR.
- Payload includes:
  - Optical and IR cameras.
  - LiDAR where possible [depends on payload capacity of UAS].
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping damage from flooding to landscape and infrastructure as GIS data, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: CONOP tests teams’ ability to collect visible and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and observers’ communications with pilot in command. This would a post-event operation to build assessment maps of the full extent of the damage. CONOP evaluates how large UAS can fly automated missions as well as manual operations when needed. Payloads are carried to support decision makers to assess the impact to infrastructure and landscape and the recovery effort post SAR missions.

## 1.8 Use Case: Tornado

### *1.8.1 Summary*

- Use Case 1: Response, sUAS/lUAS, Post-event, SAR for survivors, (B)VLOS, TIR high quality data is critical
- Use Case 2: Response, lUAS, Post-event, Damage extent, BVLOS, EO/TIR/LiDAR, no real-time

Table 8. Tornado Use Cases.

| Tornado use cases | | |
|---|---|---|
| Mission Details | #1 | #2 |
| Before/During/After | After | After |
| Hazard details | Search and Rescue for survivors/building safety | Damage assessment |
| Response/Preparedness | Response | Response |
| Type of Flight | Part 107/TFR/Waivers | Part 107 Waivers + SGI |
| Type of LOS | (E➔ B)VLOS | VLOS to BVLOS |
| Type of UAS | sUAS | Multiple sUAS and lUAS |
| UAS Design | Rotor | Rotor + Fixed wing |
| UAS Aircraft | TBD | TBD |
| Flight details | Short flights, analyze area, Flying in and out of buildings. Testing C2 links. | Large scale assessment of damage from Tornado and close-in damage assessment |
| Payload | EO/TIR | EO/TIR/LiDAR |
| Data Collected | Images and Video | Images and video |
| Product and Use | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Post-flight: DSM/DEM, Orthomosaics, Geotagged images/video |
| Notes | Real-time data back to GCS and shared with decision manager. | Derived maps of damage |

### *1.8.2 Use Case #1: Thermal/EO for search and rescue and damage assessment*

CONOP operates as soon as a SAR effort is deemed necessary.

(1) SAR operations with optical and thermal cameras search for survivors in impacted zones
(2) Thermal and optical data is collected to support damage assessment.

First small UAS used is given the ability for short term campaigns and in VTOL form provides flights from small take-off and landing spaces. Also, second small UAS is flying in and out of building. Mission will examine C2 links for navigation and data being streamed back to command center.

(1) Focus is on streaming back optical and thermal data to the GCS and on to the ICC as well as air and ground response units performing SAR missions; (2) Focus is also on collecting optical and thermal data to rapidly develop 3D models of the infrastructure to support damage assessment by the ICC and response authorities.

BVLOS and Part 107 or SGI waivers are needed to support operations for sUAS if aerial coverage is extensive. Ground based tracking DAA may be required to support BVLOS, as the VTOL sUAS may not have onboard DAA.

Payloads include optical and thermal cameras to provide real-time feed to GCS.

- Missions Include:
  - V➔BVLOS operations for SAR operations after tornado and damage assessment.
  - SAR for survivors and initial damage assessment of tornado.
  - SUAS to fly in and out of buildings, testing data stream and GPS to IMU based C2.
- Hazards include:
  - Major Tornado.
  - Collapse and/or at-risk infrastructure.
  - Population at-risk/lost.
  - Other response aircraft and non-response aircraft in airspace.
  - Towers and powerlines.
- Types of flight include:
  - Post-event: short flights to perform SAR and assess buildings impacted by tornado.
- UAS to be used:
  - Small UAS #1: VTOL with rapid flight time, quick turnaround, ability to move to new take-off sites quickly, payload capacity for EO/TIR.
  - Small UAS #2: VTOL and ability to fly into and out of structures to assess damage/SAR.
- Payload includes:
  - Optical and thermal infrared cameras.
- Products may include:
  - Real-time: Images and video to GCS and onto incident command.
  - Post-processed: Geotagged Imagery, DSM/DEM models, mapped hazardous zones in GIS data, 3D model of impacted area, and orthomosaic maps.

<u>Benefits include:</u> Operations to show how small UAS can be used for SAR and provide real-time data back to decision makers and response teams. Demonstration of the SGI process. Showing

how multiple UAS can support initial SAR and damage assessment during post-tornado event. Testing command and control (C2) capabilities for flights internally within structures.

### *1.8.3 Use Case #2: Damage assessment of impact to infrastructure for recovery efforts*

CONOP is to collect thermal and optical imagery and video of the full extent of the damage caused by the tornado. This occurs once use case #1 would have completed SAR and initial building surveys. Use case #2 supports recovery operations.

Focus is to collect data to map building damage and areas at risk for continued collapse. Data allows assessment of required recovery effort and understanding of the full extent of the tornado's impact on the infrastructure.

Large UAS is flown at higher altitude to provide full assessment of damage. Small UAS #1 is flown at lower altitude and employs directed flights from large UAS data to examine specific areas. Small UAS #2 provides mission team the ability to get in close and examine safety of structures. Second small UAS is flown by first responders/damage assessment teams on ground. Large UAS and first small UAS are flown from command center or main launch site.

Payloads include EO and TIR sensors. Post flight products include orthomosaic maps of the tornado damage as well as digital surface models of the flown flight area. If possible, LiDAR sensor captures high resolution data to map the landscape.

- Missions Include:
  - BVLOS operations to map extent of tornado impact.
  - Damage assessment of infrastructure and landscape from tornado.
- Hazards include:
  - Major Tornado.
  - Major damage to infrastructure.
  - Recovery assessment needed.
  - Other response aircraft.
  - Non-response aircraft.
  - Towers and powerlines.
- Types of flight include:
  - Post-event: Map extent of damage, evaluate at-risk infrastructure, assessment of recovery operations needed.
- UAS to be used:
  - Large UAS: Long endurance flights over the damaged area.
  - Small UAS #1: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR.
  - Small UAS #2: fast, nimble, close in assessment of building safety for recovery efforts.
- Payload includes:
  - Optical and thermal infrared cameras.
  - LiDAR where possible [depends on payload capacity of UAS].
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping tornado damage to landscape and infrastructure as GIS data, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: CONOP tests teams' ability to collect visible and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and communication among flight crewmembers. Post-event operation's ability to build assessment maps of the full extent of the damage. Long endurance small UAS and fast nimble small UAS flown at the same time as well as large UAS above both. Automated flight routes as well as manual operations for targeted data collection to support recovery efforts and damage assessment.

## 1.9 Use Case: Terrorism

### *1.9.1 Summary*

- Use Case 1: Response, sUAS, Post-event, SAR for survivors, VLOS, TIR high quality data is critical E→B)VLOS→
- Use Case 2: Response, multiple sUAS and lUAS, Post-event, Damage extent, (E→B)VLOS, EO/TIR/LiDAR, no real-time
- Use Case 3: Response, sUAS and lUAS, During, Airport surveillance, VLOS to BVLOS, EO/TIR
- Use Case 4: Response, sUAS, During, Disruption and counter measures, VLOS, Cargo cables/EO/TIR

Table 9. Terrorism Use Cases.

| Terrorism use cases | | | | |
|---|---|---|---|---|
| Mission Details | #1 | #2 | #3 | #4 |
| Before/During/After | After | After | During | During |
| Hazard details | SAR for survivors/building safety | Damage assessment | Airport/Airfield surveillance/inspection | Attack/Disrupt and counter measures |
| Response/Preparedness | Response | Response | Response | Response |
| Type of Flight | Part 107/TFR/Waivers | Part 107/TFR/Waivers | Part 107/TFR/Waivers | Part 107 |
| Type of LOS | (E→ B)VLOS | BVLOS | sUAS: VLOS; lUAS: BVLOS | VLOS |
| Type of UAS | sUAS | Multiple sUAS and lUAS | sUAS and lUAS | sUAS |
| UAS Design | Rotor | Rotor and Fixed wing | Rotor | Rotor |
| UAS Aircraft | TBD | TBD | TBD | TBD |
| Flight details | Short flights, analyze area, Flying in and out of buildings. Testing C2 links. | Large scale assessment of damage from explosion, Focused close-in inspection | sUAS: short flights and tethered to the fence lUAS: Long endurance monitoring | sUAS to attack or disrupt terror operations and identify countermeasures |
| Payload | EO/TIR | EO/TIR/LiDAR | EO/TIR with zoom | Cargo cables/EO/TIR |
| Data Collected | Images and Video | Images and video | Images and video | Images and video |

| | | | | |
|---|---|---|---|---|
| Product and Use | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Post-flight: DSM/DEM, Orthomosaics, Geotagged images/video | Real-time: Images and video to GCS<br>Post-processed: Geotagged Images, orthomosaics, enhanced images /video | Real-time: Images/video to GCS<br>Post-processed: Geotagged time stamped products |
| Notes | Real-time data shared with<br>decision manager | Derived maps of damage | Inspection of airports/airfield<br>during event | Three sUAS flights at same<br>time with different roles |

### *1.9.2 Use Case #1: Search and rescue and building damage assessment*

CONOP is to operate as soon as a SAR effort is deemed necessary. This CONOP will be a single building terrorism attack where small UAS provide VTOL/hybrid capabilities.

(1) SAR operations with optical and thermal cameras searches for survivors in impacted zones
(2) Thermal and visible data are collected to support infrastructure safety analysis

Small UAS are used given their ability for short term campaigns and in VTOL form ability to provide flights from small take-off and landing spaces. Small UAS will be flying in and out of the impacted building. Mission will examine continued command-and-control (C2) links for navigation and data being streamed back to GCS and command center.

(1) Focus is on streaming back optical and thermal data to the GCS and onto the incident command center as well as those emergency managers performing ground SAR; (2) Focus is also on collecting optical and thermal data to rapidly develop 3D models of the infrastructure to support those in the incident command team to assess the safety of the structure. BVLOS and Part 107/SGI waivers are needed to support operations; might also have TFR in place. Ground based tracking and onboard DAA support BVLOS, as the VTOL small UAS may not have onboard DAA. Payloads include optical and thermal cameras to provide real-time feed to GCS.

- Missions Include:
  - VLOS to BVLOS operations to perform SAR operations straight after terrorist event and assess building safety.
  - SAR for survivors and initial damage assessment of event.
  - SUAS to fly in and out of buildings, testing data stream and GPS to IMU based C2.
- Hazards include:
  - Terrorism event in large city.
  - Collapse and/or at-risk infrastructure.
  - Population at-risk/lost.
- Types of flight include:
  - Post-event: short flights to perform SAR and assess buildings impacted by event.
- UAS to be used:
  - Small UAS: VTOL with rapid flight time, quick turnaround, ability to move to new take- off sites quickly, payload capacity for EO/TIR.
- Payload includes:
  - Optical and IR cameras.
- Products may include:
  - Real-time: Images and video to GCS and onto incident command.
  - Post-processed: Geotagged Imagery, DSM/DEM models, mapped hazardous zones in GIS data, 3D model of impacted area, and orthomosaic maps.

Benefits include: Operations show how small UAS can be used for SAR and provide real-time data back to decision maker. Operations demonstrate SGI process; show how multiple UAS may be flown at once.

### *1.9.3 Use Case #2: Damage assessment of infrastructure for recovery efforts*

CONOP collects thermal and optical imagery and video of the full extent of the damage caused by terrorism. This is a large-scale mission to examine impact of terrorism event over multiple buildings and potentially across the whole of an international airport. This occurs once use case #1 has completed the SAR and initial building surveys. Use case #2 supports recovery operations. Focus is to collect data to map building damage, and areas at risk for continued collapse

Large UAS is flown at higher altitude to provide full assessment of damage. Small UAS #1 is at lower altitude and completes directed flights from large UAS data to examine specific areas. Small UAS #2 provides mission team the ability to get in close and examine safety of structures. Second small UAS is flown by first responders/damage assessment teams on ground. Large UAS and first small UAS are flown from command center or main launch site. Payloads include EO and TIR sensors. Post flight products include orthomosaic maps of the damage as well as digital surface models of the flown flight area. If possible, LiDAR sensor captures high resolution data to map the landscape.

- Missions Include:
  - VLOS →BVLOS operations to map extent of impact.
  - Damage assessment of infrastructure and landscape.
- Hazards include:
  - Terrorism event in large city or airport.
  - Major damage to infrastructure.
  - Recovery assessment needed.
- Types of flight include:
  - Post-event: Map extent of damage, evaluate at-risk infrastructure, assessment of recovery operations needed.
- UAS to be used:
  - Large UAS: Long endurance flights over the damaged area.
  - Small UAS #1: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR.
  - Small UAS #2: fast, nimble, close in assessment of building safety for recovery efforts.
- Payload includes:
  - Optical and thermal infrared cameras.
  - LiDAR where possible [depends on payload capacity of UAS].
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping damage to landscape and infrastructure as GIS data, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: Tests teams' ability to collect visible and TIR data over large area. CONOPS evaluates how mission responds to other UAS and communication among crewmembers. Post-event operations build assessment maps of the extent of the damage. Long endurance sUAS and fast nimble small UAS are flown at the same time as well as large UAS above both. Automated flight routes and manual operations for targeted data collection support recovery efforts and damage assessment.

### 1.9.4 Use Case #3: Tethered UAS Airfield Inspection to Include Runways, Taxiways, and Fences

CONOP is to utilize unmanned aircraft on airport property to inspect critical infrastructure components quickly and effectively. sUAS with tethering capabilities are flown near airport barrier fences, runways, and taxiways to examine structure and identify debris. sUAS are flown under VLOS and as a Part 107 mission to examine fence integrity. Large UAS are flown (E → B)VLOS and with additional sensors to detect debris/assess damage on runways and taxiways. Missions are flown with individual UAS for use case and potentially with other UAS in the vicinity.

Post flight products include orthomosaic maps that have been inspected as well as DEM/DSM models of the flown flight area including identification of any discrepancies needing immediate or urgent attention. Images will be stored for future cross-examination of property damage.

- Missions Include:
  - Small UAS Part 107 VLOS flights.
  - Other sUAS in the vicinity.
  - Large UAS: EVLOS & BVLOS Waivers.
- Hazards include:
  - Flight operations of manned aircraft.
  - Potential for Radar/Communications Disruptions.
- Types of flight include:
  - During: Record area and conduct real time inspection using video capabilities.
- UAS to be used:
  - Small UAS #1: VTOL multirotor with integrated cameras. Tethered internally to fence lines and runway areas for extended flights.
  - Small UAS #2: VTOL multirotor with integrated cameras. Tethered externally to fence lines and runway areas for extended flights.
  - Large UAS: VTOL Multi-rotor with long range/endurance and image processing capability for damage and debris determination.
- Payload includes:
  - Optical and thermal infrared camera systems with zoom capability.
  - Autopilot and GPS.
- Products may include:
  - Real-time: Images and video to GCS.
  - Post-processed: Geotagged Imagery, orthomosaics, enhanced imagery and video.

Benefits include: The ability to stream optical data back to the GCS which can be passed to the Command Center. Operators and imagery analysts evaluate the condition of the structure being inspected and how best to respond. Communications with Remote Pilot-in-command will be immediate in the event of a need for more focused inspection of an item.

### *1.9.5 <u>Use Case #4</u>: Airport UAS Threat scenario*

CONOP is to demonstrate the capability of small UAS to effectively attack or disrupt operations at an international airport and identify countermeasures necessary for a real-world attack.

For the attack scenario, complete cooperation with the airport and response teams is required. Small UAS are flown under VLOS operations by qualified Part 107 Remote Pilots. Coordination with a command center and local authorities is essential in a safe and successful testing. Payloads include EO and TIR sensors as well as GPS technology and autopilot functions.

Missions are flown with individual UAS for the use case and with other UAS in the vicinity.

Post flight products are not made available to the public, however an After-Action Review (AAR) would be required to capture lessons learned. Feedback and information findings gained will be incorporated in an appropriate airport emergency response plan.

- Missions Include:
  - Small UAS Part 107 VLOS flights.
  - Other sUAS in the vicinity.
- Hazards include:
  - Operational airport with manned aircraft.
  - Operations in/on/around critical infrastructure.
- Types of flight include:
  - During: Record entire process via video and documentation.
- UAS to be used:
  - sUAS #1: Multi-rotor with integrated EO/TIR for short flights (drop capable).
  - sUAS #2: Multi-rotor with EO/TIR for medium range (water balloon or inert explosive device).
  - sUAS #3: Fixed wing battery operated for longer range (larger onboard weight limit).
- Payload includes:
  - Cargo drops capable x 2.
  - Optical and thermal infrared cameras x 3.
  - Autopilot capabilities.
- Products may include:
  - Real-time: Images and video to a Testing Command Center.
  - Post-processed: Geotagged Imagery, time stamped, Flight tracking information.

<u>Benefits include:</u> CONOPS tests teams able to demonstrate, in a controlled environment, a threat capability an airport has never been required to respond to before. By conducting this simulated attack test and evaluation an airport would be more adequately prepared for a real-world scenario that includes multiple disruptions by sUAS, bordering the likeness of a swarm attack on an airport. Identification of steps necessary in an Emergency Plan will undoubtedly be realized.

## 1.10 Use Case: Nuclear Dispersion

### *1.10.1 Summary*

- <u>Use Case 1</u>: Response, sUAS, Ongoing, VLOS, EO/TIR high quality data is critical, Extent of damage
- <u>Use Case 2</u>: Response, lUAS, Ongoing, BVLOS, Air quality sampling of toxic chemicals
- <u>Use Case 3</u>: Response, sUAS/lUAS, Post-event, Damage extent, (B)VLOS, EO/TIR/LiDAR
- <u>Use Case 4</u>: Response, sUAS, During, Disruption and counter measures, VLOS, EO/TIR

Table 10. Nuclear Dispersion Use Cases.

| Nuclear Dispersion use cases | | | | |
|---|---|---|---|---|
| Mission Details | #1 | #2 | #3 | #4 |
| Before/During/After | During | During | After | During |
| Hazard details | Heat from nuclear event | Toxic plume sampling | Damage assessment | Attack/Disrupt and counter measures |
| Response/Preparedness | Response | Response | Response | Response |
| Type of Flight | COA/TFR/Waivers | COA/TFR/Waivers | COA | Part 107 |
| Type of LOS | VLOS ➔ EVLOS | VLOS ➔BVLOS | BVLOS | VLOS |
| Type of UAS | sUAS | S(l)UAS | lUAS | sUAS |
| UAS Design | Rotor or Fixed wing | Rotor or fixed wing | Fixed wing | Rotor |
| UAS Aircraft | TBD | TBD | TBD | TBD |
| Flight details | Short flights, mapping thermal signals | Sampling of dispersal, sUAS close in, lUAS for downwind | Large scale assessment of damage from explosion | sUAS to attack or disrupt terror operations and identify countermeasures |
| Payload | EO/TIR | EO/TIR/Gas sampler | EO/TIR/LiDAR | Cargo cables/EO/TIR |
| Data Collected | Images and video | Images, video, 3D map of plume and concentrations | Images and video | Images and video |

| | | | | |
|---|---|---|---|---|
| Product and Use | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Real-time: Geotagged images and toxic plume levels | Post-flight: DSM/DEM, Orthomosaics, Geotagged images/video | Real-time: Images/video to GCS<br>Post-processed: Geotagged time stamped products |
| Notes | Real-time data back to GCS and shared with decision manager. | Real-time data back to GCS and shared with decision manager. | Derived maps of damage | Three sUAS flights at same time with different roles |

### 1.10.2 Use Case #1: *Thermal mapping of nuclear explosive site*

CONOP is to support team to map damage and continued explosive potential of a nuclear reactor. Focus is on rapid response missions and short flights to collect optical and thermal imagery and video of the damaged reactor. There is a need for multiple flights to rapidly assess a changing environment.

Mission includes EVLOS to BVLOS operations with possible waivers (SGI and/or Part 107) with potential TFR in place given that the flight team will need to be outside any zones to minimize exposure.

Payloads include EO and TIR sensors. Products include optical and thermal orthomosaic maps nuclear explosion site. Data and products are provided to the local incident command to support their decision-making process.

- Missions Include:
  - EVLOS to BVLOS operations to support observations of highly volatile environment.
  - SGI or Part 107 waivers needed. Main need rapid response with TFR in place.
  - Continued missions to support data collection over site to assess progression, risk to local infrastructure and population centers, and potential for further explosive events.
- Hazards include:
  - Volatile nuclear site.
  - Potential for further events.
  - Impact to local community and infrastructure.
- Types of flight include:
  - During: Rapid response flights to support data collection.
- UAS to be used:
  - Small UAS: Fixed wing/VTOL with short endurance for rapid turnaround on flights and payload capacity for EO/TIR.
- Payload includes:
  - Optical and thermal infrared cameras.
- Products may include:
  - Real-time: Images and video to GCS and onto incident command.
  - Post-processed: Geotagged Imagery, DSM/DEM, mapped explosion site in visible and thermal format as GIS data, 3D models of impacted area, and orthomosaic maps.

Benefits include: Proximity missions that demonstrate how small UAS can collect data in high-risk environment, that would not be possible from ground observer and/or manned flights. Real-time stream of data to GCS and/or incident command. Short rapid response flights. Could be multiple small UAS at one time. Assessment of coordination needed for multi-UAS operations.

### 1.10.3 Use Case #2: *Toxic plume sampling*

CONOP is to sample toxic plumes from nuclear explosion and downwind toxic clouds to assess their potential impact to population, infrastructure, and transportation networks. Two options of sampling could be completed with one mission, depending on the endurance of the UAS.

UAS fly through these potentially toxic plumes and clouds without putting personnel at-risk. Focus is to collect optical and thermal data of the plumes and clouds and measurements of the gases emitted. Mission includes BVLOS operations with SGI waivers - large UAS operations. Small UAS are flying at the same time under Part 107 with possible SGI or Part 107 waivers for operations. Note that TFR will be in place over the impacted site as well as potentially over at-risk zones downwind of the event.

Large UAS is used given distance that flight team is situated from location of nuclear explosion and to analyze potential risk to population from radiation leaks. Small UAS fly short term campaigns to analyze radiation levels to minimize risk for ground teams so that they can access impacted zones.

Downwind cloud analysis requires long endurance flights to assess full extent of toxic dispersal to determine composition of the release. Data support emergency responders in providing appropriate protective actions to the State to base decisions on affecting public safety. Use of the UAS will decrease exposure to collection teams in the field.

Onboard DAA is useful and/or mission requires ground-based tracking capabilities. Payloads include EO and TIR sensors along with capability to measure gas concentrations. Products include 3D profiles of the gas concentrations but downwind of the release site for population safety using large UAS as well as proximal to the release to support ground teams in the field using small VTOL.

- Missions Include:
    - Small UAS: VLOS operations to sample proximal plumes ➔ minimize risk to teams.
    - Large UAS: BVLOS to sample concentrations from plumes and downwind clouds.
    - SGI and or Part 107 waivers needed, TFR in place over toxic plume locations.
    - Continued sampling of plume from explosion site and downwind clouds.
- Hazards include:
    - Toxic plumes and clouds emitted from nuclear explosion.
    - Ground teams at risk from toxic plume and need real-time assessment of hazards.
    - Population centers and infrastructure at-risk.
    - Downwind impact to aviation community and local communities.
    - Large dispersal zone of toxic clouds.
- Types of flight include:
    - During: Large UAS long endurance flights to sample gas concentrations along with ability to re-sample plumes and clouds based on data collected. Small UAS shorter flights to gain understand of situation. Both types of UAS operating at the same time. TFR in place and could apply SGI for large UAS operations.
- UAS to be used:
    - Small UAS: VTOL for short period flights to sample plumes and support assessment on minimizing exposure to ground teams.
    - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR as well as sampling equipment to measure the toxicity levels of plumes and clouds.
- Payload includes:
    - Optical and thermal infrared cameras as well as gas sampling equipment to detect radiation leaks and survey downwind locations for toxic dispersion.
- Products may include:

- Real-time: Images and video to GCS and onto incident command.
- Post-processed: Geotagged Imagery, DSM/DEM, mapped eruptive area in visible and thermal format as GIS data, 3D models of impacted area, and orthomosaic maps.

Benefits include: BVLOS operations and possible SGI/COA/TFR testing. Real-time and/or post processing of plume/clouds for decision making at incident command. Long duration flights to sample plumes and assess if likelihood of further dispersal downwind. Both small and large UAS flown at the same time. Automated missions over defined routes as well as adaptable flight routes to focus on at-risk locations and to obtain data on toxic plume and cloud concentrations.

#### *1.10.4 Use Case #3: Damage assessment from explosion and gas dispersal for recovery efforts*

CONOP is to collect thermal and visible imagery and video of the full extent of the damage caused by a nuclear event including explosion and toxic plume and clouds. Focus is to collect data to map building damage and areas at risk for continued collapse. Also, data to support analysis of the impact that toxic plume and clouds has on local infrastructure and landscape.

Payloads include EO and TIR sensors. Post flight products include orthomosaic maps of the damage as well as digital surface models of the flown flight area. If possible, LiDAR sensor could capture high resolution data to map the landscape.

- Missions Include:
  - BVLOS operations to map extent of impact.
  - Damage assessment of infrastructure and landscape.
- Hazards include:
  - Large nuclear explosion.
  - Major damage to infrastructure.
  - Toxic plumes and clouds impact to downwind communities and infrastructure.
  - Recovery assessment needed.
- Types of flight include:
  - Post-event: Map extent of damage, evaluate at-risk infrastructure, assessment of recovery operations needed.
- UAS to be used:
  - Large UAS: Fixed wing/VTOL with long endurance and payload capacity for EO/TIR.
- Payload includes:
  - Optical and thermal infrared cameras.
  - LiDAR where possible [depends on payload capacity of UAS].
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping damage to landscape and infrastructure as GIS data, and orthomosaic maps. If collected, LiDAR Point Cloud/3D model of the landscape.

Benefits include: CONOP tests teams' ability to collect visible and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and observers' communications with pilot in command. This would a post-event operation to build assessment maps of the full extent of the damage.

### *1.10.5 Use Case #4: Nuclear Power Plant UAS Threat scenario*

CONOP is to demonstrate the capability of small unmanned aircraft to effectively attack or disrupt incursion into nuclear plant and identify countermeasures necessary for a real-world attack.

For the attack scenario, complete cooperation with the nuclear plant security and response teams is required. Small UAS are flown under VLOS by qualified Part 107 Remote Pilots. Coordination with local authorities essential in a safe and successful testing.

Payloads include EO and TIR sensors as well as GPS technology and autopilot functions. Missions are flown with individual UAS for the use case and with other UAS in the vicinity.

Post flight products are not made available to the public, however an AAR is required to capture lessons learned. Feedback and information findings gained are implemented in an appropriate airport emergency response plan.

- Missions Include:
  - Small UAS Part 107 VLOS flights.
  - Other sUAS in the vicinity.
- Hazards include:
  - Incursion of other UAS into a Nuclear power plant.
  - Operations in/on/around critical infrastructure.
- Types of flight include:
  - During: Record entire process via video and documentation.
- UAS to be used:
  - sUAS #1: Multi-rotor with integrated EO/TIR for short flights (counter act).
  - sUAS #2: Multi-rotor with EO/TIR for medium range flight (record incursion UAS).
- Payload includes:
  - Optical and thermal infrared cameras x 3.
  - Autopilot capabilities.
- Products may include:
  - Real-time: Images and video to a Testing Command Center.
  - Post-processed: Geotagged Imagery, time stamped, Flight tracking information.

Benefits include: CONOP team demonstrate, in a controlled environment, a threat capability to a nuclear power plant and how to respond to a sUAS airborne threat. By conducting this simulated attack test and evaluation, a power plant can be more prepared for a future event that includes multiple disruptions by sUAS, bordering the likeness of a swarm attack on the facility. Identification of steps necessary in an Emergency Plan will undoubtedly be realized.

## 1.11 Use Case: Train Derailment

### *1.11.1 Summary*

- <u>Use Case 1</u>: Response, sUAS, Post-event, SAR for survivors, (E)VLOS, TIR HQ critical
- <u>Use Case 2</u>: Response, multiple sUAS, Post-event, Damage extent, (E)VLOS, EO/TIR, no real-time

Table 11. Train Derailment Use Cases.

| Train Derailment use cases | | |
|---|---|---|
| Mission Details | #1 | #2 |
| Before/During/After | After | After |
| Hazard details | Search and Rescue for survivors | Damage assessment |
| Response/Preparedness | Response | Response |
| Type of Flight | Part 107/SGI/TFR/Waivers | Part 107 waivers |
| Type of LOS | (E➔ B)VLOS | VLOS to EVLOS |
| Type of UAS | sUAS | Multiple sUAS |
| UAS Design | Rotor | VTOL |
| UAS Aircraft | TBD | TBD |
| Flight details | Short flights, analyze area | Large scale assessment of damage from derailment and close up assessment |
| Payload | EO/TIR | EO/TIR |
| Data Collected | Images and Video | Images and video |
| Product and Use | Real-time: Geotagged images/video<br>Post-flight: DSM/DEM, Orthomosaics | Post-flight: DSM/DEM, Orthomosaics, Geotagged<br>images/video |

### 1.11.2 *Use Case #1: Search and rescue for survivors*

CONOP operates as soon as a SAR effort is deemed necessary. SAR operations with optical and thermal cameras search for survivors on train. The CONOP supports analysis of any spills from a train derailment. This would be a finite volume and supports the first responders to assess the safety of the derailment and any issues that result from spilled oil or other liquids from the train.

Small UAS are used given their ability for short term campaigns and in VTOL form to provide flights from small take-off and landing spaces. UAS focuses on streaming back optical and thermal data to the GCS and on to the incident command center as well as those emergency management teams performing ground SAR.

BVLOS and SGI/Part 107 waivers support operations, depending on the extent of the derailment. Ground based tracking supports BVLOS, as the VTOL small UAS may not have onboard DAA. Payloads include optical and thermal cameras to provide real-time feed to GCS.

- Missions Include:
  - VLOS to BVLOS to perform SAR operations straight after train derailment.
  - SAR for survivors and initial damage assessment of event including any spills.
- Hazards include:
  - Significant train derailment.
  - Collapse and/or at-risk rail network infrastructure.
  - Passengers at-risk/lost.
  - Spill hazard from train fuel/oil that could lead to explosion.
- Types of flight include:
  - Post-event: short flights to perform SAR and assess rail network impacted by event.
- UAS to be used:
  - Small UAS: VTOL with rapid flight time, quick turnaround, ability to move to new take- off sites quickly, payload capacity for EO/TIR. Flying multiple to provide assessments of train and/or rail network infrastructure.
- Payload includes:
  - Optical and IR cameras.
- Products may include:
  - Real-time: Images and video to GCS and onto incident command.
  - Post-processed: Geotagged Imagery, DSM/DEM models, mapped hazardous zones in GIS data, 3D model of impacted area, and orthomosaic maps.

Benefits include: Operations to show how small UAS can be used for SAR and provide real-time data back to decision maker. Demonstrate SGI process. Show how multiple UAS may be flown at once.

### 1.11.3 *Use Case #2: Damage assessment on rail network infrastructure for recovery efforts*

CONOP is to collect thermal and optical imagery and video of the full extent of the damage caused by derailment and to assess the structural safety of the train carriages for movement and recovery process. The CONOP includes assessment of fuel/oil on the landscape and if a clean- up is required along with any post-event recovery to the rail network.

CONOP occurs when use case #1 has completed a SAR and initial train and rail infrastructure surveys are completed. Use case #2 supports recovery operations. Focus is to collect data to map damage and areas at risk for continued collapse as well as to determine if any fuel/oil is still on the land and impacting the vegetation or has potential for future hazards.

First small UAS with Part 107 waiver flies at higher altitude to understand the full extent of the impact to infrastructure. Second small UAS flies in close to impacted area to capture data on damaged structures. Payloads include EO and TIR sensors. Post flight products include orthomosaic maps of the damage as well as digital surface models of the flown flight area.

- Missions Include:
    - BVLOS operations to map extent of impact.
    - Damage assessment of train and impacted rail network.
- Hazards include:
    - Train derailment.
    - Major damage to rail infrastructure.
    - Recovery assessment needed.
    - Spill hazard from train fuel/oil that needs clean-up/assessment of further hazard.
- Types of flight include:
    - Post-event: Map extent of damage, evaluate at-risk infrastructure, assessment of recovery operations needed.
- UAS to be used:
    - Small UAS #1: VTOL with endurance and payload capacity for EO/TIR.
    - Small UAS #2: VTOL close into the damaged infrastructure [bridge/train station/rails].
- Payload includes:
    - Optical and thermal infrared cameras.
- Products may include:
    - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping damage to landscape and infrastructure as GIS data, and orthomosaic maps.

<u>Benefits include:</u> CONOP tests teams’ ability to collect visible and/or TIR data over a large area. Operations would evaluate how missions respond to other UAS and observers’ communications with pilot in command. Post-event operation to build assessment maps of the full extent of the damage.

## 1.12 Use Case: All – Medical Supply and Communications for 1st Responders

### *1.12.1 Summary*

- Use Case 1: Response, sUAS, Post-event, Medical Supply Delivery to at-risk areas, BVLOS, Optical and ability to carry cargo
- Use Case 2: Response, s(l)UAS, Post-event, Continued communications links for first responders, BVLOS, Optical with integrated C2 to command center

Table 12. All Use Cases.

| All use cases | | |
|---|---|---|
| Mission Details | #1 | #2 |
| Before/During/After | Post-event | After |
| Hazard details | Medical supply and lifesaving equipment delivery | Airborne communications hub |
| Response/Preparedness | Response | Response |
| Type of Flight | COA/TFR/Waivers | COA/TFR/Waivers |
| Type of LOS | BVLOS | sUAS: VLOS<br>lUAS: BVLOS |
| Type of UAS | sUAS | sUAS and lUAS |
| UAS Design | Rotor and Fixed wing | Fixed wing |
| UAS Aircraft | TBD | TBD |
| Flight details | Short flights into at-risk locations where no road network exists | sUAS: Short spot flights for first responder sites<br>lUAS: Long term flights with communications system |
| Payload | EO with cargo capability | EO with communications on board |
| Data Collected | Images and Video | Images and video |
| Product and Use | Real-time: Geotagged images/video/Cargo drop off | Real-time: Geotagged images/video/C2 links for first responders |

| | | |
|---|---|---|
| Notes | Real-time data back to GCS and shared with decision manager. | Real-time images sent to GCS, C2 links to command center |

### 1.12.2 *Use Case #1: Medical supply deliveries for at-risk locations*

CONOP focuses on getting critical lifesaving supplies and equipment to at-risk locations and those where there is no road access. Small UAS are used given ability for short term campaigns and in VTOL form to provide flights from small take-off and landing spaces. They have capacity to carry cargo that can get supplies to the at-risk communities impacted by the disaster and that can't be reached by those first responders on the ground.

Focus is on streaming back optical data to the GCS and on to the incident command center as well as those emergency managers performing ground search and rescue. Also, focus is on how to land or drop off supplies and have the aircraft return to the take-off site for a follow-on mission. Need exists for BVLOS and waivers to support operations unless TFR in place or the distance from take-off to at-risk community is flyable under Part 107 regulations. Ground based tracking and onboard DAA support any BVLOS, as the VTOL small UAS may not have onboard DAA. Payloads include optical cameras to provide real-time feed to GCS as well as capacity to carry cargo for the supply delivery.

- Missions Include:
  - BVLOS operations straight after disaster event to get critical supplies to those at-risk and those blocked from receiving ground-based first responder care.
  - Drop or land and take-off at the final location to get supplies to at-risk population.
- Hazards include:
  - Disaster that cuts off certain communities from ground-based first responder support.
  - Population at-risk/lost and need access to critical supplies, such as medical and food.
- Types of flight include:
  - Post-event: short flights to perform cargo delivery of supplies.
- UAS to be used:
  - Small UAS: VTOL with rapid flight time, quick turnaround, ability to move to new take- off sites quickly, payload capacity for EO and cargo carrying capacity.
  - Large UAS: Fixed wing with long endurance to reach cut-off community.
- Payload includes:
  - Optical cameras [integrated] with payload capacity to carry and drop off cargo.
- Products may include:
  - Real-time: Images and video to GCS and onto incident command as well as ability to drop off cargo and return from at-risk site to original take-off for follow on mission.

Benefits include: Operations to show how small UAS can be used critical supply delivery for at-risk locations and those cut off from ground support. Demonstrate how aircraft can drop off supplies without landing and/or landing with take-off from remote location. Test real-time data stream of optical data for GCS and rapid response flights to support as many at-risk locations.

### 1.12.3 *Use Case #2: Airborne communications relay for on-ground first responders*

CONOP provides airborne communications support to a disaster response where ground-based communications have been knocked out from the disaster. Focus provides short-term flights for spot locations with small UAS as well as long term flights for hours at a time where a large UAS provide continued communications at higher altitude and above the complete disaster response location. UAS payloads include EO and TIR sensors so at the same time as providing communications hub, they map and monitor the disaster. The intent is to develop a system in line with the cases from National Public Safety Telecommunications Council Technology and Broadband committee whose UAS and Robotics Working Group 2018 report proposed to aerial land mobile radio (LMR) or long term evolution (LTE) capabilities on a UAS.

#1: LMR on tethered UAS provides radio support and all those on the ground switch to UHF frequency provided from drone to connect to command center.

#2: UAS operates as vehicle repeater so EM personnel switch to match and use channels.

#3: LMR is available via UAS between two groups of ground 1st responders and acts as a repeater.
#4: UAS provides coverage to restore LTE to connect ground personnel to the command center

- Missions Include:
  - sUAS: VLOS flights, short rapid response, communication hub to command center.
  - lUAS: BVLOS flights, long term, higher altitude, continued communication hub for hours to days from ground response to command center.
- Hazards include:
  - Major Disaster and ground communication network is not functional.
  - First responders need communication link to command center for response.
- Types of flight include:
  - Post-event: Flights under TFR or SGI to get airborne communication hub available to support first responders. Short-term with small UAS; long-term with large UAS.
- UAS to be used:
  - Small UAS: VTOL for rapid take-off and airborne to get communications running.
  - Large UAS: Fixed wing with long endurance for hours to days of communications hub.
- Payload includes:
  - Optical and thermal IR cameras to support SAR efforts.
  - On-board communications network to connect ground responders back to command center.
- Products may include:
  - Post-processed: Geotagged Imagery, DSM/DEM models, Mapping damage to landscape and infrastructure as GIS data, and orthomosaic maps.

<u>Benefits include:</u> CONOP tests ability to collect data over a large area. Operations evaluate how missions respond to other UAS and observers' communications with PIC. Mission evaluates ability to get aerial communications network in place when ground network is non-functional. Test how small UAS and large UAS work together, and permissions needed to respond.