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Innovation Center for Earth Sciences
U. S. GEOLOGICAL SURVEY
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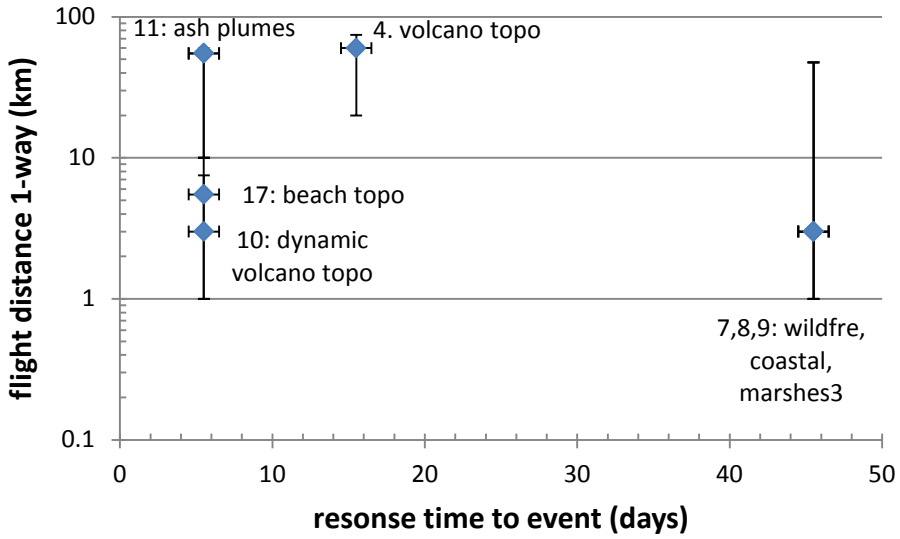
Natural hazards needs for UAS: results of a breakout from the May 19-21 Federal UAS workshop at USGS Headquarters

Introduction

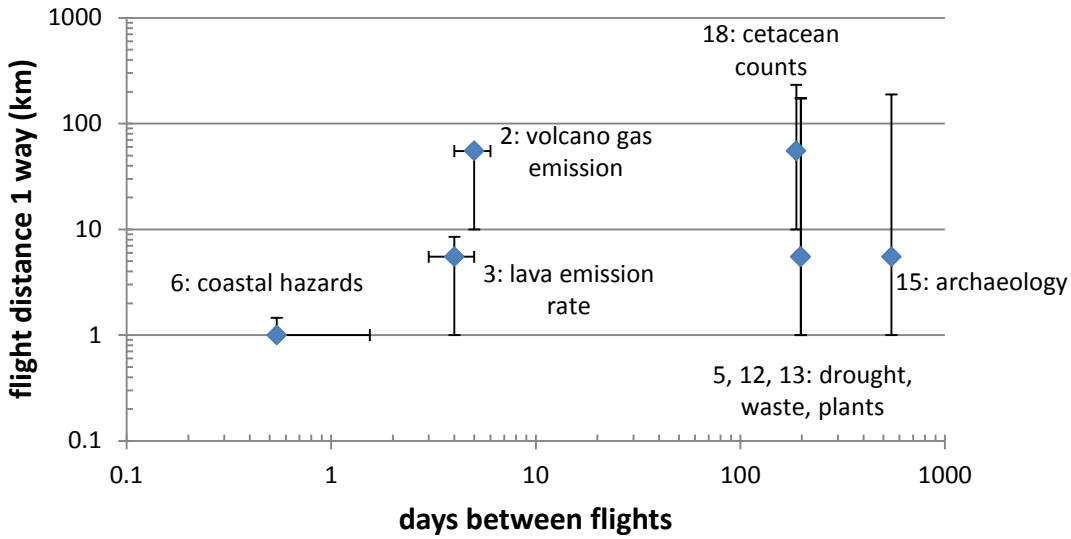
The USGS Land Remote Sensing Program and Innovation Center for Earth Sciences hosted speakers and leadership from Federal Agencies exploring UAS technologies at a Federal UAS workshop at USGS Headquarters from May 19-21, 2015. The purpose of the workshop was to inform USGS and DOI scientists and leadership about current and future opportunities with UAS technology and to raise Federal leadership awareness of UAS technology. Participation from major Federal agencies included DOE, DOI (USGS, BLM, BOEM), EPA, NASA, NOAA, NSF and USFS. As part of the workshop, elements of these agencies gathered together in a breakout meeting to explore applications of UAS to natural hazards. The goal of the breakout was to draw together a number of potential natural hazards use cases for UAS. **These can be used to help focus future UAS planning and operational capabilities to achieve a reduced set of mission characteristics, including payload, flight duration, frequency and perhaps the most challenging factor, response time.**

Below we list a number of use cases from participants. These include responses to emerging and on-going volcanic, coastal, flooding and landslide hazards, marine hazards (oil spills), and wildfires. Payloads listed below include gas samplers, imagers for Particle Image Velocimetry (PIV), multi/hyperspectral imagers, and passive imagers for topography and topographic change detection from SFM (structure-from-motion). Participants listed some of the parameters that data from each sensor would have to meet for their use cases. Use cases indicate a need to determine the optimal imager for SFM, and lightweight multi-/hyperspectral imagers and gas samplers. The challenge of how to achieve PIV over evolving flows is also notable.

We found that we could separate use cases into broad categories of **monitoring vs. response**. Monitoring missions can be planned with advance warning. Frequency of data collection and mission duration are dominant mission planning choices. Response missions are more challenging because they require many of the capabilities of monitoring mission, but at short response times that challenge current use of the National Airspace. Yet these rapid response missions may represent the most valuable uses of small UAS because reduced platform planning and logistics may give us the ability to collect data during short-lived events. Below we summarize these results as:



Range of response times and 1-way flight distances from surveys, annotated by number shown below.



Range of acquisition frequencies and 1-way flight distances from survey, annotated by number shown below.

Next Steps

1) We think developing feasible rapid response scenarios for a small number of these events may represent one of the most valuable contributions of future Federal UAS workshops. Developed with OAS and other partners, those scenarios might allow us to gracefully deploy small UAS at the short timescales required to respond to emerging hazards.

2) It is not clear to us where to look for the optimal sensors for each of the use cases below, so this topic need to be explored at the next UAS workshop.

Participants, Federal UAS Workshop breakout on hazards applications:

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Angie Diefenback (USGS Volcano Science Center)
Cindi Werner (USGS Volcano Science Center)
Victoria Avery (USGS Volcano Hazards Program)
Skye Corbett (USGS Geology Science Center)
Brian Zelenke (BOEM)
Lynn Torak (USGS South Atlantic Water Science Center)
Greg Desmond (USGS Eastern Geographic Science Center)
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Jonathan Glen (USGS Geology Science Center)
Jody Waugh (DOE)
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Ajit Sampay (USGS EROS)
Chris Sherwood (USGS Woods Hole)
Jonathan Stock (USGS)

Submitted use cases, Federal UAS Workshop breakout on hazards applications

What if we could:

1) Forecast where oil spills effects are headed (**response, passive**)
    a. What: detection of oil layer thickness
    b. Flight distance: 10-100+ km
    c. Flight duration: 10/15 hours
    d. Response time (min/max): 1/10 days
    e. Sensors: imager
    f. Resolution (max/min): 0.01/0.1 m
    g. Notes: BOEM's planning/permitting for oil and gas operations offshore on the U.S. outer continental shelf (OCS) involves an assessment of associated risk from pollutant spills (viz. oil spills). The ability to more accurately and precisely measure spill incidents, track their progress, and determine the pollutant fate would improve quantification of these risks. UAS have the potential to be rapidly deployed to survey hazardous material spills out at sea under conditions unfavorable to manned aircraft and with decreased risk to personnel. UAS capable of operating more than 200 km offshore would be needed to

provide coverage to encompass those areas on the OCS under consideration. To aid in achieving this range, it would be desirable to have UAS capable of being launched and recovered from ships/other platforms (e.g., buoys, oil rigs) at sea. Sensors capable of detailed image and video capture (1080p) in the visible spectrum would be primary in determining slick location, spill trajectory, resources at risk, oil weathering, and oil volume/thickness. Outside the visible spectrum, of particular interest would be experimental sensors capable of estimating the thickness of an oil slick. Sensor technologies under investigation for this purpose include variants of LiDAR, UV laser fluorescence, microwave radiometry, side-looking aperture radar (SAR), and others.

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2) Forecast explosive volcano eruptions using gas emission surveys (**monitoring, sampler**)
    a. What: Staged UAS assets to perform gas concentrations downwind at summit height.
    b. Flight distance: 10-100 km
    c. Flight duration: 5-10 hours
    d. Frequency: 4-6 times/year
    e. Sensors: gas (SO_2, H_2S,CO_2, BrO)
    f. Resolution (max/min): X ppm?
    g. Notes: ruggedized for high winds
    h. Contacts:
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3) Forecast explosive volcanic eruptions using lava emission-rate estimates. Estimate eruption duration and changes in eruptive behavior. (**monitoring/response, passive**)
    a. What: Collect imagery for change detection using photogrammetry.
    b. Flight distance: 10 km
    c. Flight duration: 1-5 hours
    d. Frequency: event driven (hourly/daily/weekly)
    e. Sensors: imager
    f. Resolution (max/min): 0.1/1 m
    g. Notes: ruggedized for high winds
    h. Contacts:
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4) Create updateable models of lahar run-out with topographic models (**response, passive**)
    a. What: Collect imagery for topographic modeling.
    b. Flight distance: 20-100 km
    c. Flight duration: 1-5 hours
    d. Response time (min/max): 1/30 days
    e. Sensors: imager, SAR or LiDAR

f. Resolution (max/min): 1/12 m
g. Notes: ruggedized for high winds
h. Contacts:
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5) Monitor drought effects on water table (**monitoring, passive**)
    a. What: Removing soil moisture component from GRACE gravity changes. Thermal IR gets surface soil moisture changes at surface, model subsurface
    b. Flight distance: 10 km
    c. Flight duration: 1-5 hours
    d. Frequency (min/max): 30/365 days
    e. Sensors: multispectral with thermal IR 1070-1100 nm range
    f. Resolution (max/min):
    g. Notes:
    h. Contacts:
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6) Evaluate coastal hazards at inlets to decide management (**monitoring, passive**)
    a. How much water moving in and out using PIV.
    b. Flight distance: 1 km
    c. Flight duration: 13 hours
    d. Frequency (min/max): 2/24 hours
    e. Sensors: RBB + near IR + maybe real thermal (heat structures are traceable)
    f. Resolution (max/min): Sufficient to track ~5 cm foam, flotsam, seeded particles
    g. Notes: PIV needs specialized high-frame rate camera with adjustable focal planes. Movable balloon platform? Scientific questions are: how has the inlet affected water levels inside the bay? How much sand is bypassing the inlet and what are the effects of modified sediment budget on adjacent shorelines? Will the inlet close naturally, widen, or migrate? Inlets are small but may have multiple shallow channels. It is difficult to measure water velocities, but particle-image velocimetry of surface currents might be possible from UAS or tethered system video. This is research-level science. Goal would be to estimate volume of water discharge over tidal cycles. Measurements would have to be conducted from system hovering over channel sections for minutes at a time over a 13 hour tidal day. Measurements might need to be made a neap and spring tides, and frequently enough (~4 times a year?) to capture changes associated with morphological changes.

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7) Monitor post-wildfire erosion to determine the origin of debris-flow sediment and to gain insight on where to mitigate burned hillslopes? (**response, passive**)
    a. What: change detection of eroding topography from sfm
    b. Flight distance: 1/5 km
    c. Flight duration: 1/6 hours
    d. Response time (min/max): 1/90 days
    e. Sensors: imager
    f. Resolution (max/min): 0.01/0.1 m
    g. Notes: The origin of sediment that gets entrained in debris-flows is currently debated. Does most of the sediment originate in channels, or on hillslopes? One way to measure this is to use UAS to fly over a burned watershed and map the topography using Sfm immediately after a burn and before any erosion. After a rainstorm event, we should then re-map the topography, and create an elevation difference map between the original and eroded topography. This will show the spatial distribution of erosion, which will help us to determine the source of sediment that is eroded in debris flows. Moreover, that will provide insight into how the locations that should be targeted during mitigation.
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8) Determine whether your house is safe from coastal retreat? (**monitoring/response, passive**)
    a. What: Erosion of coastal cliffs and fissure detection from topographic change detection to identify risk.
    b. Flight distance: 1/5 km
    c. Flight duration: 1/6 hours
    d. Frequency (min/max): 1/90 days
    e. Sensors: imager
    f. Resolution (max/min): 0.01/0.1 m
    g. Notes: Cliffs (Calif.), bluffs (east coast, California), and permafrost bluffs (AK)
    h. Contacts:
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        iii. Agency/Science Center/unit: CMG Santa Cruz/EGSC Reston

9) Protect the marshes and wetlands most effective at protecting coasts (**monitoring, passive**)
    a. What: Mapping to assess ecosystem health.
    b. Flight distance: 1/5 km
    c. Flight duration: 1/6 hours
    d. Frequency (min/max): 1/90 days
    e. Sensors: multispectral imager
    f. Resolution (max/min): nm ?
    g. Notes: This is a research topic. Can we use multi or hyper spectral imaging to evaluate wetland health (stress from excess nutrients, too much/too little salt, too much/too little water)?
    h. Contacts:
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10) Forecast where lava flows are headed (**response, passive**)
    a. What: Changing topography to assess breakouts and future flow-paths.
    b. Flight distance: 1/5 km
    c. Flight duration: 1/6 hours
    d. Response (min/max): 1/10 days
    e. Sensors: multispectral imager
    f. Resolution (max/min): 0.1/1 m
    g. Notes:
    h. Contacts:
        i. Name:
        ii. Email:
        iii. Agency/Science Center/unit:

11) Forecast where ash plumes go and how fast using better models of plume movement (**response, sampler**)
    a. What: In-situ sampling for PSD and concentration and temp, composition
    b. Flight distance: 10-100 km
    c. Flight duration: 1/10 hours
    d. Response (min/max): 1/10 days
    e. Sensors: air sampler, temperature,
    f. Resolution (max/min): ?
    g. Notes:
    h. Contacts:
        i. Name:
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12) Identify at risk hazardous waste sites (**monitoring, passive/sampler**)
    a. What: Topographic change detection, vegetation change, and transpiration discharge from sites (10's to 100's of acres)
    b. Flight distance: 1-10 km
    c. Flight duration: 1/5 hours
    d. Frequency (min/max): 30/365 days
    e. Sensors: imager, multispectral imager, air sampler
    f. Resolution (max/min): ?
    g. Notes:
    h. Contacts:
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        iii. Agency/Science Center/unit:

13) Identify plant species from the air (**monitoring, passive**)
    a. What: High throughput phenotyping of plants using imaging spectroscopy

b. Flight distance: 1-10 km
c. Flight duration: 1/5 hours
d. Frequency (min/max): 30/365 days
e. Sensors: imager, multispectral imager
f. Resolution (max/min): ?
g. Notes:
h. Contacts:
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14) Develop better flood probability models (**monitoring, passive**)
    a. What: Valley network extraction from better than 10-m data
    b. Flight distance: 1-10 km
    c. Flight duration: 1/5 hours
    d. Frequency (min/max): once
    e. Sensors: imager
    f. Resolution (max/min): 0.1/1 m
    g. Notes:
    h. Contacts:
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15) Know which significant archeological sites are at risk? (**monitoring, passive**)
    a. What: Topographic change detection at cm scale
    b. Flight distance: 1-10 km
    c. Flight duration: 1/5 hours
    d. Frequency (min/max): 1/2 years
    e. Sensors: imager
    f. Resolution (max/min): 0.1/1 m
    g. Notes: And after storms with erosion. Looking for changes from erosion and human activities.
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        iii. Agency/Science Center/unit: Argonne National Lab

16) Map volcanic edifice stability (**monitoring, passive**)
    a. What: Hyperspectral & magnetics to map edifice alteration
    b. Flight distance: 1-10 km
    c. Flight duration: 1/5 hours
    d. Frequency (min/max): once
    e. Sensors: magnetic
    f. Resolution (max/min): ? nT
    g. Notes:

h. Contacts:
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17) Predict which beaches are most at risk? (**response, passive**)
    a. What: Topographic change detection (dm scale, hourly changes)
    b. Flight distance: 1-10 km
    c. Flight duration: 1/5 hours
    d. Response time (min/max): 1/10 days
    e. Sensors: imager
    f. Resolution (max/min): 0.01/0.1 m
    g. Notes: Wave run-up depends on shape of beach; current estimates use most recent LiDAR to estimate beach width and beach slope, but a) actual shape of beach when storm hits may be different and b) run-up really depends on the complete shape of the beach, which may have variable slope. A better run-up model could be run with more detailed geometry. Key value of UAS measurements is ability to respond rapidly before event to assess risk.
    In addition, detailed before / after measurements of topography is important tool for research to improve models of beach erosion. In addition to static maps and changes maps, SFM data can provide info on sediment size, vegetation, and moisture content...all important inputs to model and also to evaluation of habitat for e.g. plovers.
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        iii. Agency/Science Center/unit: USGS

18) Collect counts of individual cetaceans in specific lease areas for stock assessment purposes and to evaluate the impacts of specific human activities on cetaceans. (**monitoring, passive**)
    a. What: wildlife censusing
    b. Flight distance: 10-100 km
    c. Flight duration: 10/15 hours
    d. Frequency (min/max): 10/360 days
    e. Sensors: imager
    f. Resolution (max/min): 0.01/0.1 m
    g. Notes: BOEM, NOAA Fisheries, the U.S. Navy, the oil/gas industry, and others have relied on manned aerial surveys to collect large-scale information on cetaceans (whales) for stock assessment purposes and to evaluate the impacts of specific human activities on cetaceans. The primary survey area encompasses approximately 240,000 sq. km of the northeastern Chukchi and western Beaufort seas off the north coast of Alaska. We are interested in using UAS to decrease risk to personnel, increase survey efficiency, and minimize disturbance to marine wildlife. Efforts to-date lead us to believe that capture of images and video in the visible spectrum, and to a lesser extent the infrared spectrum (thermal), will best allow detection and species identification of cetaceans in post-processing. UAS operations will need to be conducted from 500 ft. to 2,000 ft. above ground level (AGL) and up to approximately 50 nmi from the ground control station located on ship

or shore. Present efforts by BOEM to compare conventional manned aerial surveys to UAS utilize Insitu ScanEagles with a Nikon D810 single-lens reflex camera (SLR) camera and telephoto lens aimed directly downward, configured to automatically take photographs every 2-3 seconds in the visible spectrum for survey flights lasting approximately 5 hours or more. The images collected by this UAS will achieve a minimum ground resolution of 7 cm/pixel, sufficient for identifying cetaceans to species and determining whether calves are present, while maintaining a minimum strip width of 400-600 m from a survey altitude of 1,000 ft. AGL.

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