Use of Small Unmanned Aerial Systems for Tactical Response during Kilauea Volcano Lower East Rift Zone event

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***Abstract*— A team from the Center for Robot-Assisted Search and Rescue flew 28 day and 16 night sorties with four models of small unmanned aerial systems (sUAS) rotorcraft from eight locations to assist with the tactical response to the 2018 Kilauea Volcano Lower East Rift Zone event. The sorties had significant flight outcomes for responders, added value to the responders and public, and add use cases to the use of sUAS. Most notably, this was the first known use of sUAS for emergency response to an eruption, first use of rotary sUAS to sample air quality, and first live streaming of video from sUAS over the new FirstNet cellular network.**

I. INTRODUCTION

The Kilauea Volcano Lower East Rift Zone event, originally call the Leilani eruption event, is an ongoing active volcano flow from the Kilauea volcano on the Hawaii Kona or "big" island. Kileuea is a shield volcano, one that continuously oozes rather than produces catastrophic explosions like Mount St. Helens, and has been in continuous eruption since 1983. A set of dangerous eruptions began on May 3 with fissures, steam and gas vents, and slow movement of lava through the rural residential Leilani Estates neighborhood in the Puna region of the island. By May 15, 19 fissures had formed and 27 houses had been destroyed.

The Center for Robot-Assisted Search and Rescue (CRASAR) volunteered five pilots, four models of rotorcraft small unmanned aerial systems (DJI Inspire, M200, M210, and Mavic Pro), DJI Zenmuse XT2 and XT2 thermal sensors, and stinger gas meter carriers to aid the Hawaii County Civil Defense. The team was deployed in the field May 14-19, 2018, and collected 64.8GB of data (2,235 images and 63 videos). The 44 sorties for civil defense were coordinated with the University of Hawaii Hilo under a temporary flight restriction held by the fire department. The UH Hilo sUAS team concentrated on mapping the shape and extent of lava flows, whereas CRASAR was dedicated to supporting the fire department. A third team from Columbia University Earth Observatory arrived and merged with the UH Hilo team to collect data for vulcanology. The Department of Interior later provided a drone team.

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CRASAR deployment was the first known use of sUAS for tactical response during a volcanic eruption. The sorties assisted with a live welfare check on an isolated house, identified a new fissure not visible from the ground, mapped lava fronts, and provided the data by the US Geological Survey (USGS) to determine the rapid acceleration of the lava flow on May 18 at least seven hours sooner than manned inspections at daylight. It was the first known use of a rotorcraft sUAS for sampling air quality at a federally declared disaster. In addition, the missions supplied tactical situation awareness and reduced the number of helicopter deployments during the day, thereby reducing costs and risk to the crews.

II. PRELIMINARY FINDINGS

Fig. 1. Operators wearing respirators while flying due to presence of SO2.

From a disaster response perspective, the use of sUAS at the Leilani volcanic eruption is similar to, and different from, prior reported disasters. A lava eruption is similar to a flooding or wildland firefighting event because the event evolves over time and covers a wide geographic extent. Unlike flooding, but similar to wildland firefighting and mudslides, the eruption occurred in hilly terrain with trees which impact line of sight and altitudes. As with wildland firefighting, sUAS are particularly advantageous at night because manned aircraft unlikely to be allowed to fly due to safety considerations nor carry thermal imagery. sUAS may be subject to updrafts from heat, though this was not experienced. The eruption is similar to a hazardous materials event because air sampling is an important objective and because sUAS pilots may have to wear personal protection equipment (see Fig. 1). Thermal sensing was very important both day and night in assessing whether lava was hot or if portions were pre-existing and should not be factored into flow rates (See Fig. 2).

Fig. 2. Views from DJI 210 carrying a video camera and XT2 thermal camera of fissure 17 on May 16, 2018.

The sorties were for three major mission types: reconnaissance, debris estimation, and tactical situation awareness. They illustrate six use case of strategies for supporting tactical operations:

- *Night flying.* 16 of the 44 sorties were flown at night, providing situation awareness of the lava flows, the speed at which they moving, where they were moving and how they might cut off evacuation routes. The CRASAR team identified the occurrence of a new fissure on May 16 and, working with the US Geological Survey team in the field, identified the sudden acceleration of the lava on May 18.
- *All weather aircraft.* The sorties made use of the DJI M200 and M210 rotorcraft, both of which are waterproof, which was critical for working in the frequent tropical rain showers. Whereas the imaging sensors carried by the platforms were not waterproof, the platform and the circulation of air from the propellers essentially protected them.
- *Flights at 300 meters).* Flying above the general 121 m limit offered significant advantages. It allowed the operators to maintain visual line of sight over longer distances and eliminated radio interference from trees and terrains. This increased the safety of the operators because they had to move less home land/launch sites less often. It also increased safety because the sUAS had to spend less time in the air because each image captured a bigger footprint. The increased altitude did not reduce the efficacy of the imagery; responders and geologists could clearly see the lava and relevant features at that altitude.
- *Coordinating multiple sUAS*. The CRASAR team flew three sUAS simultaneously from the same location in order to minimize the operator's exposure to the out-gassing fissure. Each sUAS was assigned a separate altitude (61, 121, and 300 m).
- *Live streaming.* Real-time imaging from the Inspire was live streamed to the responders at the incident command post and emergency operations center over a FirstNet wireless connection.
- *Hangar Enterprise Platform for rapid reconnaissance.* Hangar 360 is an app that autonomously launches a sUAS, goes to 300ft, takes 24 images as it pans and tilts the camera, lands, uploads the images to cloud, and produces a stitched image that can be examined on a website in minutes. This was particularly useful for establishing general situation awareness of an portion of the Leilani Estates neighborhood or a fissure.

The deployment also saw the use of two sensors that had not been used for actual responses. Sorties were flown carrying with a four gas meter in order to sample the air for SO2 and H2S. While there had been a debate in the sUAS community as to whether the airflow from the rotorcraft would dilute the readings, in practice this was not a problem. The sUAS-carried meter may not have accurately determined the density of a gaseous plume but they were able to detect the presence of the invisible gases at different locations. Sorties were flown with the XT2 thermal sensor which produces a radiometric .jpg.

III. OTHER OBSERVATIONS

The eruption event poses at least two new research directions. One direction is in computer vision and machine learning, as steam plumes obscured many of the images. This interfered with interpreting the images and stitching them into an orthomosiac. Another direction is in human-robot interaction, as the event suggests night operations will become more prevalent; thus more work is needed in human-robot interaction, especially human factors and crew rest cycles. Data was collected on sleep and fatigue patterns of the crew.

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