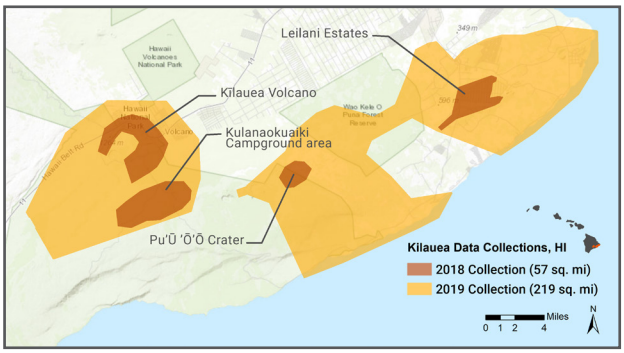
The Fire and Water of Pele

Remote Sensing to Better Understand Kīlauea

Overview

Active since May 3, 2018, **Kīlauea Volcano** on the island of Hawai'i has rapidly and dramatically changed the topography of the landscape, **awakening new excitement** among geologists and researchers for years to come. Using the U.S. Geological Survey (**USGS**) Geospatial Products and Services Contract (GPSC) in support of the **Hawaiian Volcano Observatory** (HVO), the **NV5 Geospatial (NV5G) and GEO1** team captured high resolution lidar and imagery over Kīlauea during the eruptions of 2018, and again in 2019 for a follow-up survey, with final deliverables provided in May 2020. A **complex endeavor with extraordinary requirements** and involving **extensive collaboration, ingenuity, and innovation**, the project has helped first responders and scientists to monitor conditions and assess damage during the volcano's active periods, as well as to model and predict future activity for the enhanced safety of residents.



Complexity & Innovation

To chronicle the landscape impact of an active volcano required **innovation** in the configuration and utilization of **both existing and new technologies**. Given the hazards of assessing the active craters and lava fields on the ground, an airborne remote sensing approach was the only way to acquire data safely and economically. while calderas were erupting, and lava was flowing. The NV5G/GEO1 Team acquired lidar and imagery over 57 sq. miles, including the Halema'uma'u crater, middle East Rift Zone, and lower East Rift Zone and Pu'Ū 'Ō'Ō lava flow field. The ever-changing environment required an **agility in execution** which rivaled any other remote sensing survey experienced by our acquisition team. Our solution to fly via a helicopter platform provided the flexibility and agility to collect data at **low altitude** (500 ft above ground level) under cloud cover typically present over the volcano. Our team configured a **multi-sensor package** that would provide exceptional data at this low altitude -- dual Riegl VUX-1 LR lidar sensors co-housed with Phase One iXM RGB and NIR 100MP and Oblique RGB cameras. The flights required **careful planning** to ensure complete collection of high density lidar (40-80 pulses/m^2) and imagery while also allowing for **real-time adaptions in flight height** to avoid lava vents, gas clouds, and debris. Maneuvering around local volcanic activity and hourly variable weather, the

Aerial photo showing crevice caused by land movement.

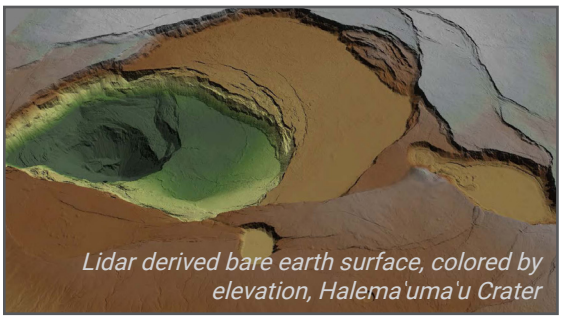
collection of this relatively small area ultimately took 11 missions and six days to complete.

Helicopter and sensors utilized

The 2019 collection focused on a much larger area (219 square miles) to characterize the new post-eruption landscape, and to serve as a **baseline to model and predict the geography and topography of future lava flows** for the enhanced preparedness and safety of residents. To provide a more robust dataset as a foundation for long term monitoring, the NV5G/GEO1 team used new technology by deploying a **unique sensor configuration package** to enable **increased point density (up to 100 pulses/m^2)** and associated accuracy. Acquisition was performed by GEO1 using a customized multi-sensor package - the **new Riegl VQ-480II** (a lightweight new sensor with UAS capability) with an integrated Phase One IXU RS-1000 4-band camera. NV5G's Riegl UAS sensor experts and the GEO1 acquisition team worked closely with the helicopter provider to ensure a tail-mounted antenna configuration which would maximize the number of available GPS/GNSS satellites, and a forward mount for full use of the UAS sensor's field-of-view.

Both data collections (2018 and 2019) required **extensive coordination and communication** with the USGS, National Park Service (NPS), and local air traffic authorities to gain access by air and ground. Coordination required teamwork, adaptability, and exceptional technical skills as the NV5G/GEO1 team communicated with approximately 20 key personnel across five agencies and organizations for daily coordination and planning. Survey crews worked closely with USGS and NPS staff to locate and tie into previously established control monumentation. In addition, notifications to communities were coordinated to ensure residents were properly informed as to the timing and purpose of all helicopter flights.

New workflows for calibration and initial processing of the data were required given the unique landscape and sensor configurations. During the 2018 collection, to enable **rapid turnaround** of critical information for real-time community response to the situation, NV5G post-processed the data within 10 hrs of each mission while on-site, then sending the data via FTP to Cold Regions Research and Engineering Laboratory for automated cloud point processing and DEM generation within another 10 hrs for immediate analysis by the USGS HVO. For the 2019 dataset collected at higher density, the collection yielded a total of 53 billion points, of which 16% modeled the ground to result in a **highly accurate ½ m bare earth DEM** of the volcanic landscape. Automated grounding algorithms were custom designed so that they accurately modeled the unique topography of the variable lava fields.



Lidar derived bare earth surface, colored by elevation, Halema'uma'u Crater

Both collections **documented groundbreaking changes** and yielded **exciting new discoveries**. The rapid analysis of data in comparison to data collected in 2011 enabled NV5G, USGS, and emergency response organizations to quickly understand the direction

and magnitude of surface changes in 2018. NV5G geodetic specialists quantified large topographic shifts, finding that some areas had shifted on the order of meters -- 1.5 meters to the east, 2 meters to the north, and a full 1 meter in elevation! In addition, on the last mission of the 2019 project, the GEO1 crew discovered and alerted the USGS HVO to a small 10-foot **body of water at the bottom of the Halemaʻumaʻu Crater**, in what would be the first time in recorded history that water had been observed inside the crater.

Kīlauea summit webcam showing a water lake 12/20/20, displaced by lava 12/24/20

The pond eventually expanded from the rising water table to a 600-ft long, 60-ft deep lake, and between December 2020 and May 2021 was boiled off and replaced with a lava lake roughly 700 ft deep. GEO1's discovery prompted new investigations into the volcano's water table, and of the potential future hazard of steam-driven explosions.

Future Value

The eruption and subsequent changes of Kīlauea made **worldwide headlines** as several media articles and news pieces covered the volcano's status, emergency response activities, changes pre- and post-eruption, and future threats. NV5G/GEO1 remote sensing data collections over the volcano were also presented in the media, bringing widespread attention to the **value of lidar and imagery** in 1) monitoring the landscape during active volcanic activity, 2) characterizing post-eruption impact to the landscape and human infrastructure; and 3) predicting future lava flow paths for hazard planning and public safety.

In the use of these technologies to **improve public safety**, remote sensing collections over Kīlauea contributed significantly to a **positive public image** of the geospatial profession -- the organizations that represent the profession (MAPPS, ASPRS), the programs that promote the data (National Geospatial Program including the 3D Elevation Program, data users (scientists, first responders, community planners), and data providers like NV5 Geospatial and GEO1. The helicopter platform with an integrated multi-sensor solution, the level of coordination in the execution of flights and data delivery, the ease of tasking through GPSC, and the teamwork facilitated by USGS all serve as a **model** for how to successfully capture remote sensing data during a natural disaster or ever-changing earth event such as a volcano.

Client Satisfaction

USGS science personnel with the Volcano Hazards Program and other local stakeholders were thrilled with the quality and timely delivery of the lidar and imagery for Kīlauea. Our team's project managers and technical personnel received USGS's highest evaluation scores possible for quality, timeliness, business relations, management, and overall customer satisfaction. As Kīlauea continues her journey of change, mapping the volcano has been a true honor for the NV5G/GEO1 team.