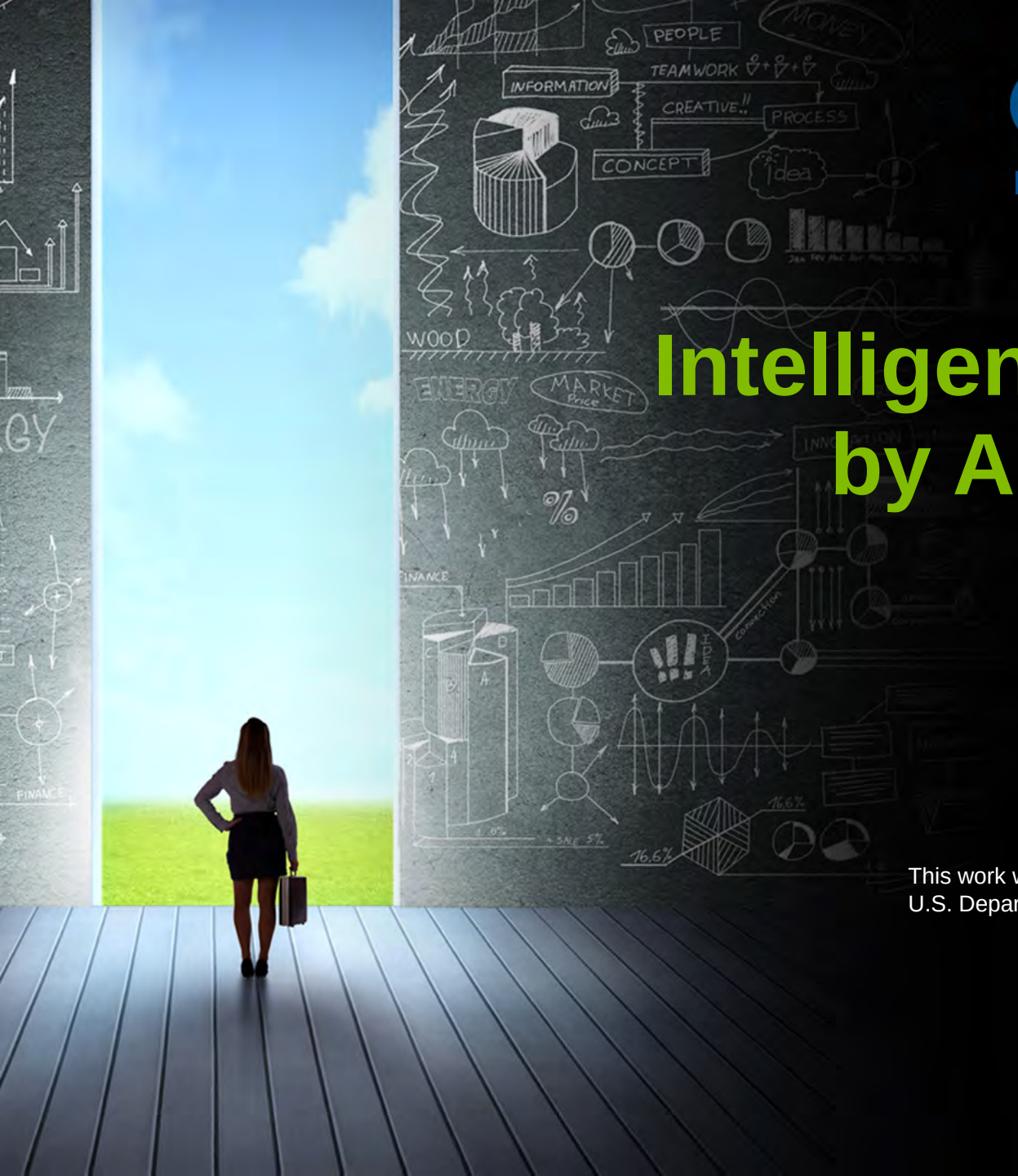

ANS Virtual Annual Meeting
Breaking Through to Deployment
2021

Intelligent Consequence Control by Aerial Reconnoiter Using Unmanned Systems

Paul Guss
Distinguished Scientist

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy. DOE/NV/03624--1101.

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Intelligent Consequence Control by Aerial Reconnoiter Using Unmanned Systems

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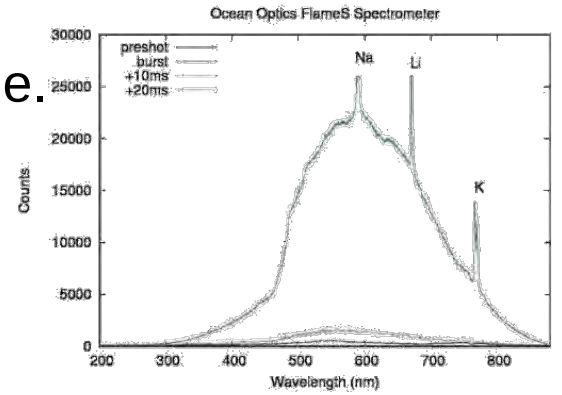
Motivation and Applications

Some environments are too difficult or risky for humans to survey and collect data.

- High radiation or radioactive contamination
- Chemical contamination
- Biological contamination
- Disaster areas (fire, flood, earthquake, oil spill, factory explosion, etc.)
- Regions of hostility (military, paramilitary, wildlife, etc.)



Small aerial drones equipped with detectors can fill a niche.

- Radiation detection and mapping
- Chemical detection, mapping, and sampling
- Biological sampling
- Optical spectroscopy
- Terrain mapping
- Video surveillance

This project has focused on radiation, chemical, and optical spectroscopy.

It has also dabbled in video and LIDAR, but has not attempted any biological applications.

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Challenges and Risks

Detector operations on small aerial drones face several challenges:

- Power, weight, and volume constraints
- Mechanical stability (vibrations, accelerations, rotations)
- Situational data (time, location, orientation)
- Communications and bandwidth limitations
- Computational limitations
- Dynamic data and extra unusual noise

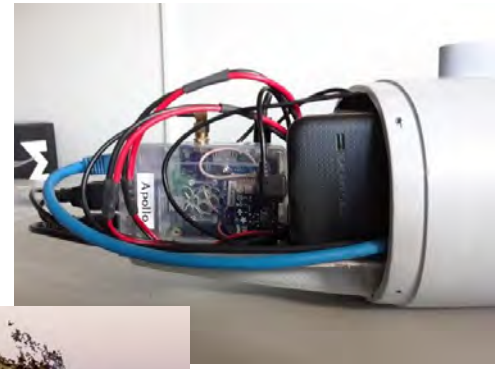
What works on the laboratory bench often breaks down in the air:

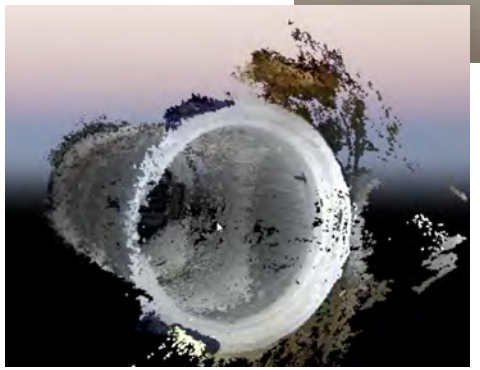
- Power interruptions and electrical noise
- Radio interference and loss of radio link
- Vibrations and shocks
- Limited computing power
- Limited dwell time for measurements
- Synchronization issues

This project has also been concerned with how to collect, transmit, store, analyze, and visualize data.

We have flown several small detectors on drones

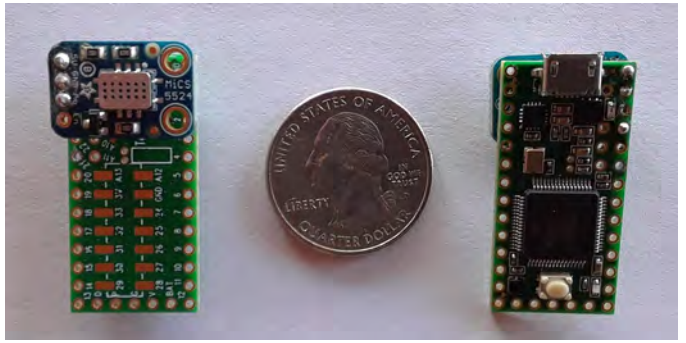
- Apollo CZT gamma imager (4 crystals for 24 cm^3)
- 3×6 and 2×2 NaI(Tl) gamma detectors with Ortec digiBASE
- 3×3 $LaBr_3$ gamma detector with Desert Eagle base
- Small Kromek CZT gamma detector (1 crystal for 1 cm^3)
- Ocean Optics optical spectrometers (Flame S,T, USB2000)
- Small chemical sensing chips (MiCS 5524, MQ-3, MQ-9, MQ-135)
- Activated charcoal sampling tubes with miniature pump and gas manifold
- LIDAR: Lightware SF-11/C, Attollo WASP 200, and Garmin LIDAR Lite
- 10 DOF telemetry and GPS chips
- GoPro Camera

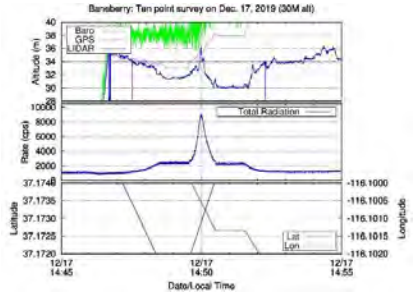




Onboard computing resources:

- Sandstorm, Harris H6, Va Tech Hexacopter, T-Rex 600, T-28
  - Raspberry Pi 3B
  - ODROID XU4 (works on bench but never flight tested)
- 3DR Solo quadcopter
  - Onboard Cortex A-9 (Yocto Linux)
  - Teensy 3.2 – Cortex M-4 (Arduino-like development)





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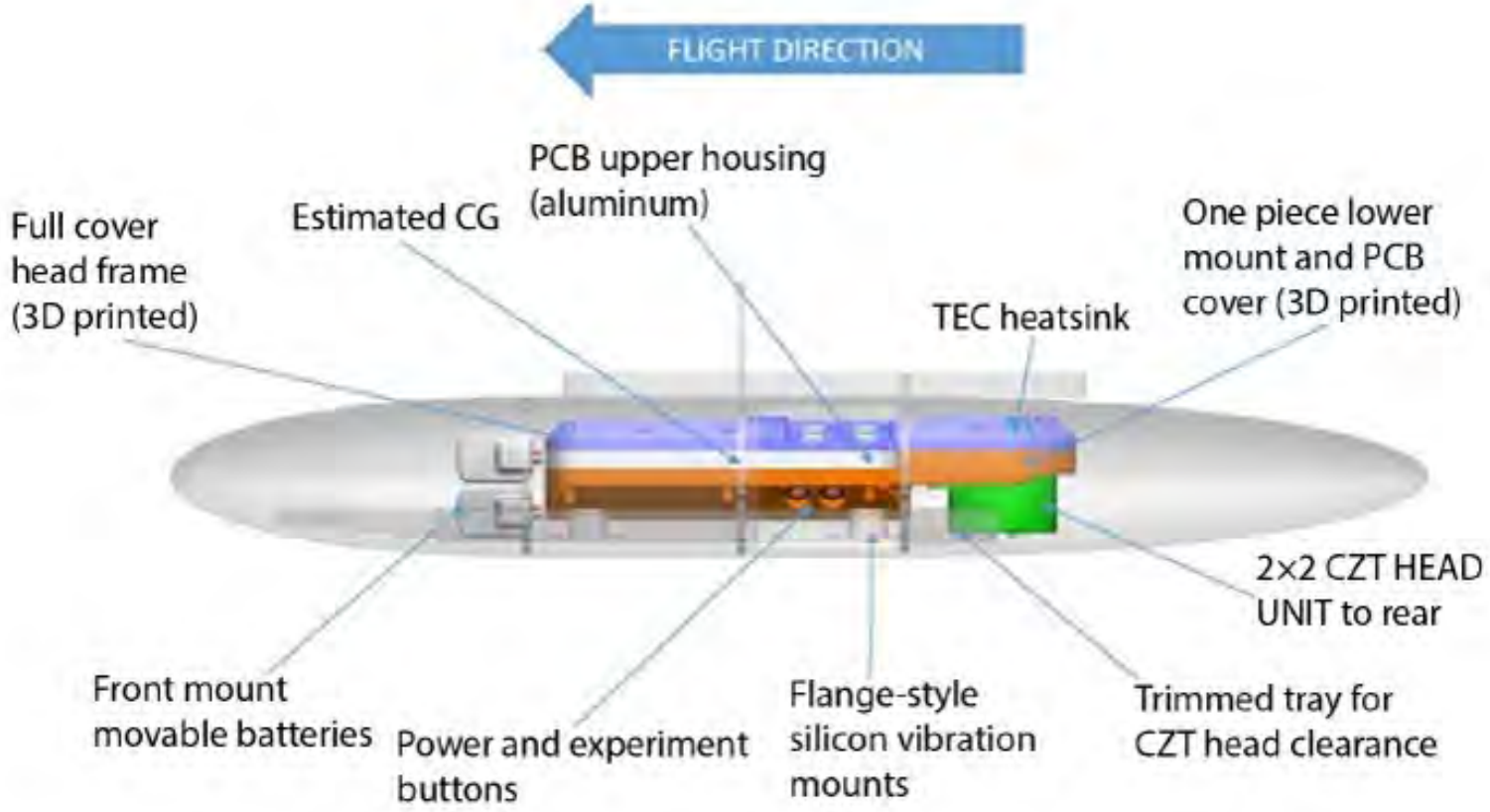
The Apollo detector and the Harris H6 are game changers

The Apollo is a high-resolution gamma spectrometer with imaging capability.
This prototype weights 10 pounds.

The Harris H6 can lift the Apollo payload and fly for ~2 hours.
And with the appropriate radio, we can fly several miles BVLOS.

The Apollo Gamma Imaging Spectrometer

The Apollo was developed by H3D, Inc. in Ann Arbor, Michigan.

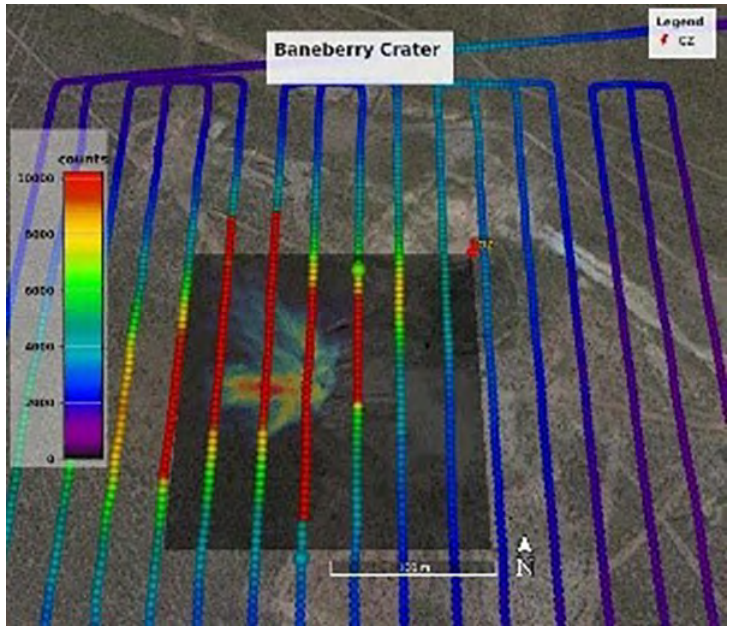


Four CZT crystals (24 cm^3) provide directional sensing via Compton back-projection.

The energy resolution is better than 1% at 662 keV.

ICARUS Autonomous Flight Planning

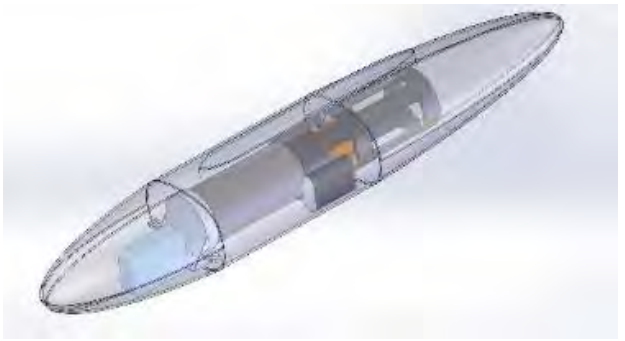
- ICARUS programming directs sUAS flight in a variety of patterns, depending on the situation. The flight can also be remotely controlled by a pilot on the ground.
- ICARUS can operate in a variety of patterns and combinations. It can fly in a quick swing over an area, a serpentine pattern, or following a plume.
- ICARUS can dwell in a 10-point V-shaped pattern in the direction of the wind, dwell at specific points of interest, and fly into tight, unmapped spaces such as tunnels.



The 3×6 NaI(Tl) Gamma Detector

At Sedan Crater on the Harris H6

At Camp Roberts on the Sandstrorm



The 3DR Solo with several detector options

RadSolo

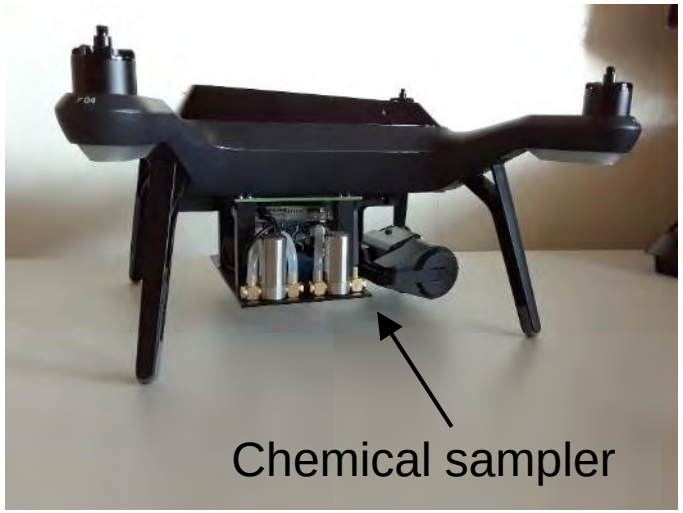
“Stubby” 2×2 NaI(Tl) detector

SpectroSolo

GoPro Hero 4 camera

Optical spectrometer

ChemSolo



Chemical sampler

The 3DR Solo is a versatile and reliable platform for flights 10–15 minutes long.

Ocean Optics optical and near-infrared spectrometer

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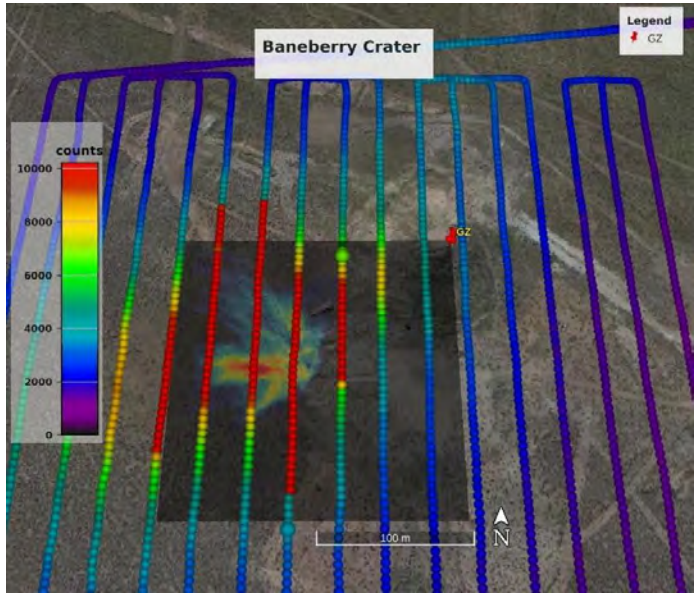
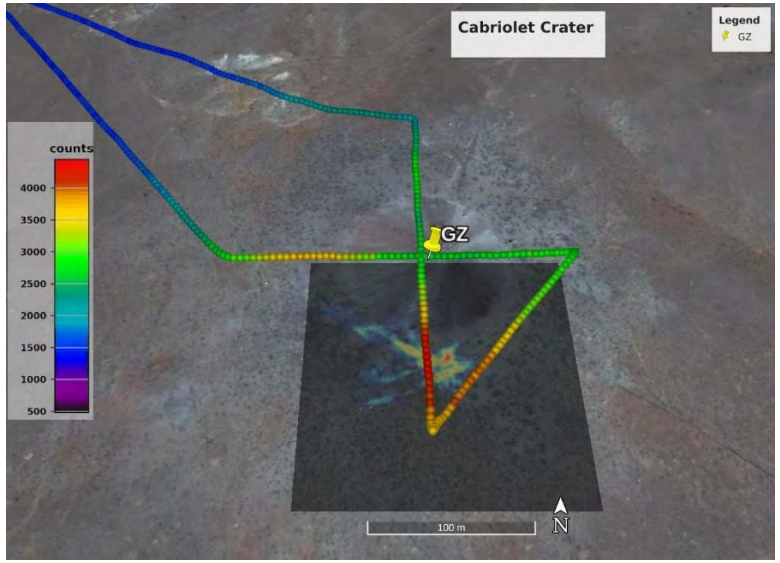
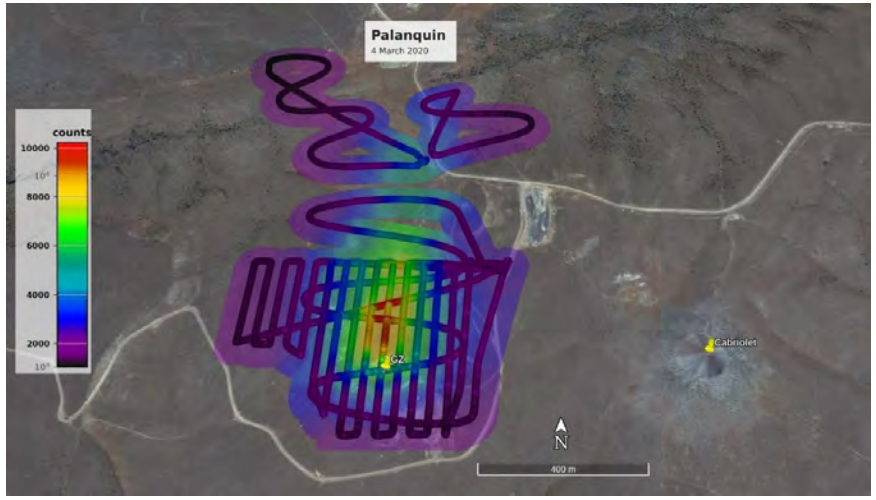
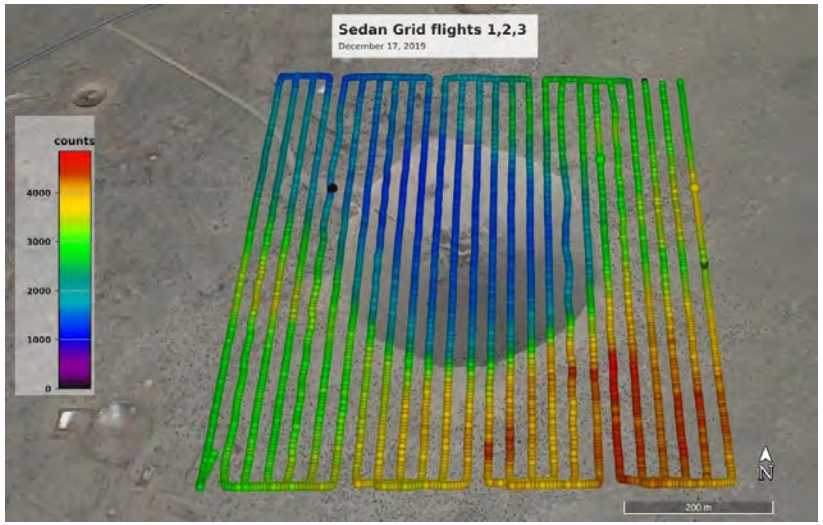
Baneberry, Cabriolet, Palanquin, and Sedan Craters

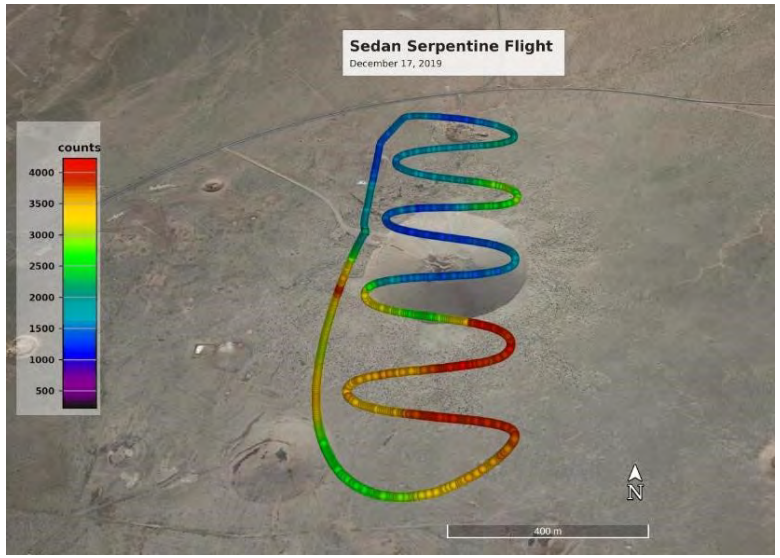
We have flown a few radiation survey and imaging missions over several craters at the NNSS.











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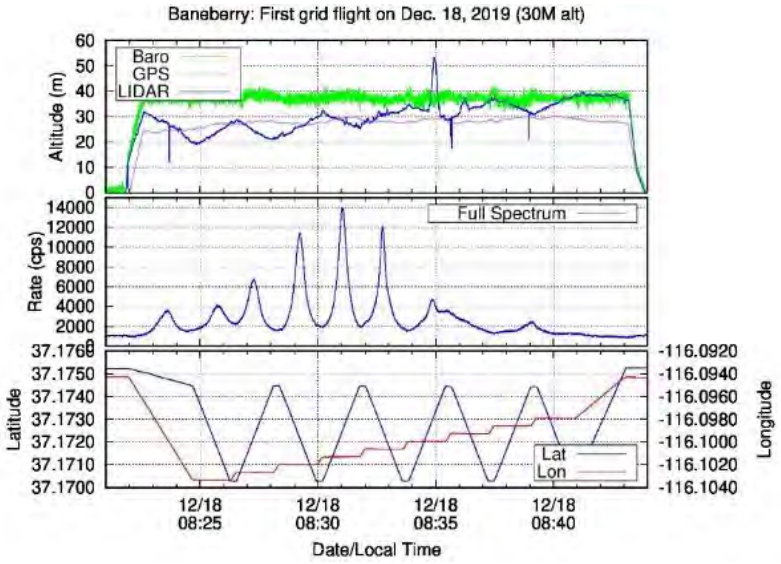
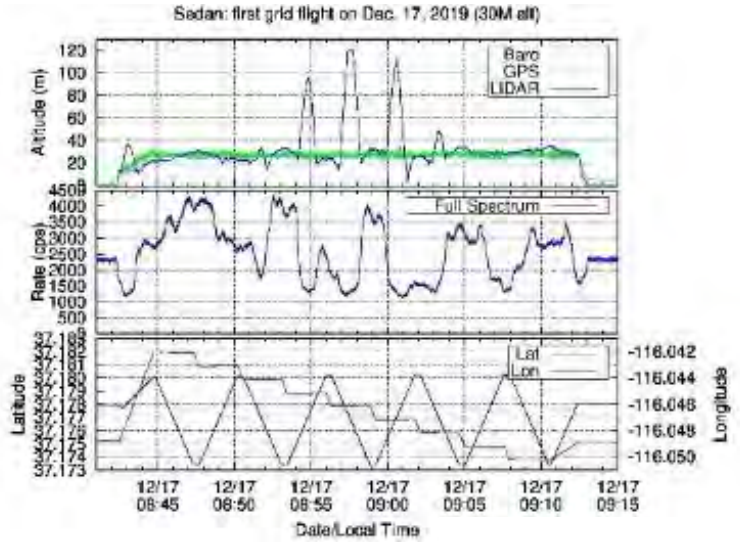


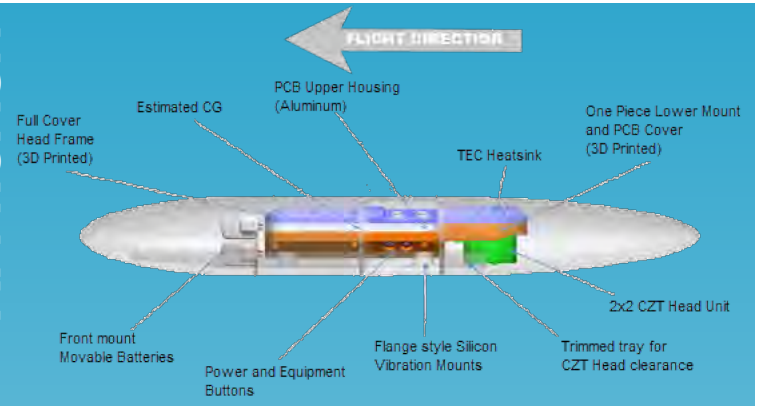


ChemBioRadNucExplosive (CBRNE) Drone Unmanned Aerial Autonomous System

R&D CHALLENGE

Harness UAS for CBRNE detection, environmental monitoring, remote sensing, aerial mapping, and meteorology

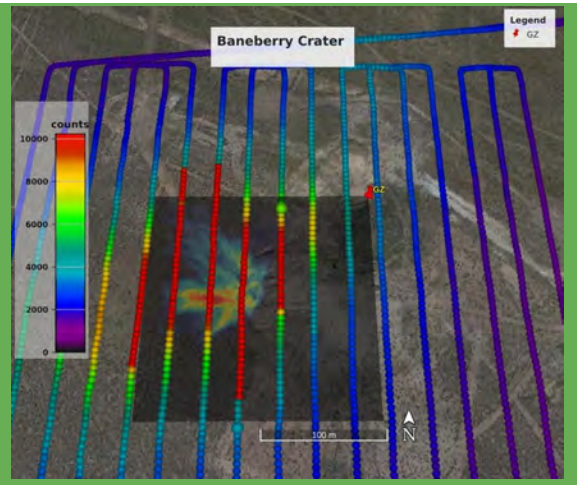
APPROACH



New hybrid heavy lift platforms combined with advanced detectors enables multitude conduct of operations. CRADA with H3D allowed new research and development of critical sensor technology.

2020 R&D 100 FINALIST

IMPACT & BENEFIT



Combined effort has pushed aerial radiation detection and measurement, emergency response, and consequence management into the UAS era

- **2015** — ***NNSS strategic initiative to develop UASs as a new capability begins***
- **2017** — ***Rotary & fixed wing radiological source detection demonstrations at Desert Rock Airfield (NNSS)***
- **2017-2018** — ***Fixed wing chemical & radiological source detection (Montana); rotary UAS chemical & spectroscopic sensors mission (Wisconsin)***
- **2018** — ***Fixed wing radiation survey proof of concept at Desert Rock Airfield (NNSS)***
- **2019** — ***Sandstorm BVLOS flights at JIFX 19-4 (Camp Roberts)***
- **2020** — ***Two BVLOS rotor wing rehearsal flights at JIFX 20-1 (Camp Roberts)***
- **2020** — ***Crater survey of Palanquin, Cabriolet, Sedan, and Baneberry (NNSS)***
- **2021** — ***GPS-denied tunnel flight (Irvine, CA)***

Summary

- A variety of detectors and platforms have been tested on complex missions.
- We are discussing a new generation of the H3D Apollo gamma imager with more crystals in a smaller package.
- Long-duration, heavy-lift flights have been challenging, but we have solutions.
- Communications in real time have also been an issue, but we are finding solutions.
- We plan to fly a neutron detector (CLYC), other chemical detectors, a multispectral IR detector, multipoint LIDAR, and possibly a mass spectrometer.
- We would like to test an aerial drop of a rotary drone by a fixed-wing drone. This would allow long-range, long-dwell-time missions.
- We are always looking for less expensive, expendable options for detectors and flight platforms.
- We are about to start flying inside underground tunnels and plan to conduct a chemical plume mapping test; possibly also a radiation mapping test.

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