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SDRD SITE-DIRECTED RESEARCH & DEVELOPMENT

# UAS sensors in difficult locations
# STL-016-20, Year 2 of 2

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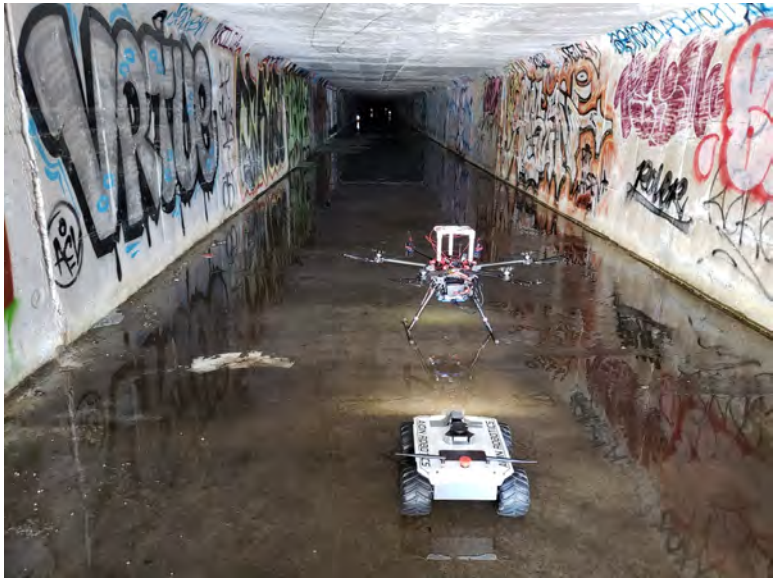
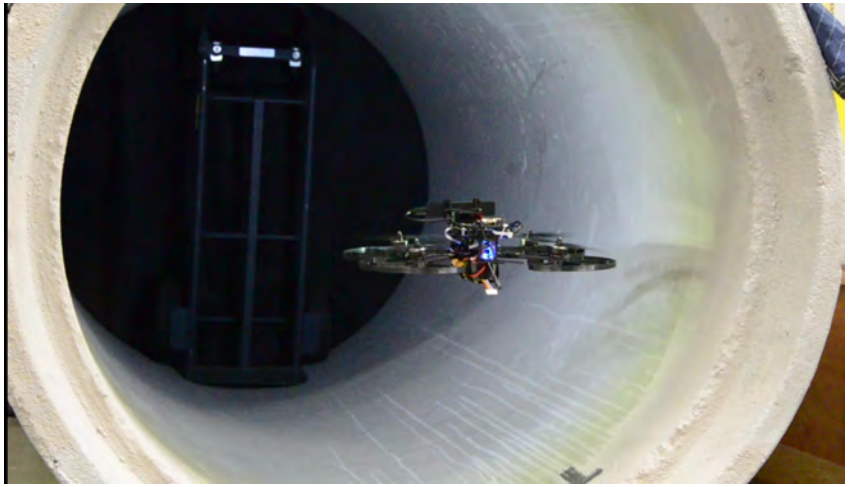
# Challenge



Situational awareness, environmental sensing, and data collection (radiation, chemical, optical) within a GPS-denied tunnel poses numerous challenges, especially considering the short range propagation of radio waves in an underground environment.



Irvine Tunnel



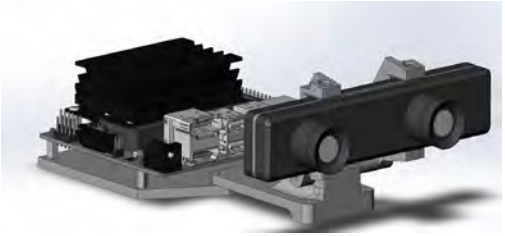
4-foot diameter pipe
(dimension of Camp Roberts tunnel)

# Innovation



OKSI Hexacopter & Rover

- Pixhawk & Jetson
- 15 minutes air time
- Synthetic GPS coordinates from SLAM



LIDAR sensor replaced by stereo camera and onboard IMU

- Real-time image processing, GPU-optimized depth data generation
- Point cloud generation

The Jetson NX provides adequate computational power

- Realtime 2D and 3D mapping
- Autonomous Navigation
- Obstacle Avoidance

# Technical Approach



In March 2021 we flew a radiation sensor & chem sensor at the Irvine tunnel.

- Many crashes
- No chem data collected

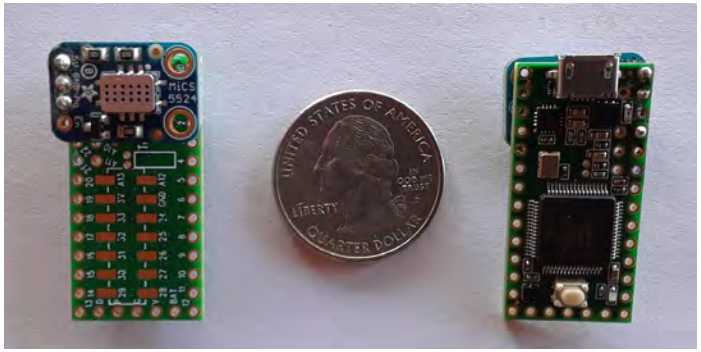
In June 2021, we flew only the chem sensor, but we also fielded the rover.

- Collected reasonably good chem data from an acetone plume.
- Tested ESP8266 Wi-Fi mesh configuration.
- Only two crashes (light from tunnel entrance blinded the camera).

# Technical Approach



MiCS5524 VOC chip on Teensy 3.2 for chem sensing



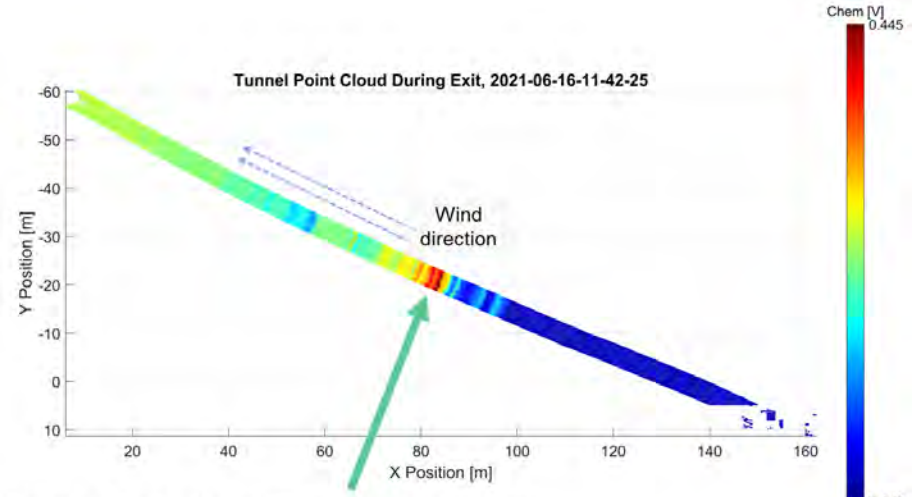

- Outputs sensor voltage and time stamp
- Sampling rate & averaging configurable
- Time stamp configurable: UTC or elapsed
- Onboard nonvolatile memory for storage
- Powered by USB
- ASCII output over USB
- Auto-starts
- Worked well in the field

ESP8266 with boost converter and 18650 battery for communications relay

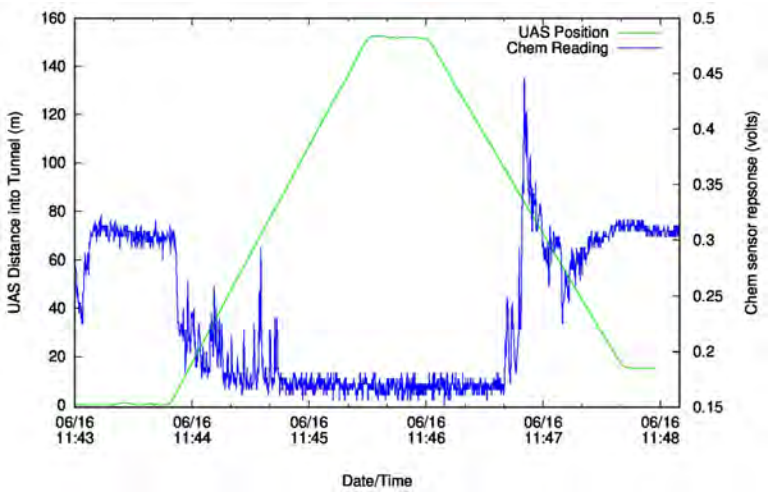
- Works as Wi-Fi extender
- Daisy chain multiple relays
- Implements full IP stack
- Port forwarding & NAT
- MQTT protocol for RSSI statistics
- A couple of hours on a coin battery
- A couple of days on 18650 battery
- Need to implement power limiting & sleep mode
- Worked in lab tests, but had dropout issues at the tunnel

# Results

Point cloud generated in real time during tunnel flight.
Chemical intensity shown as heat map and strip chart.




Chemical Spike Near UGV + Acetone location

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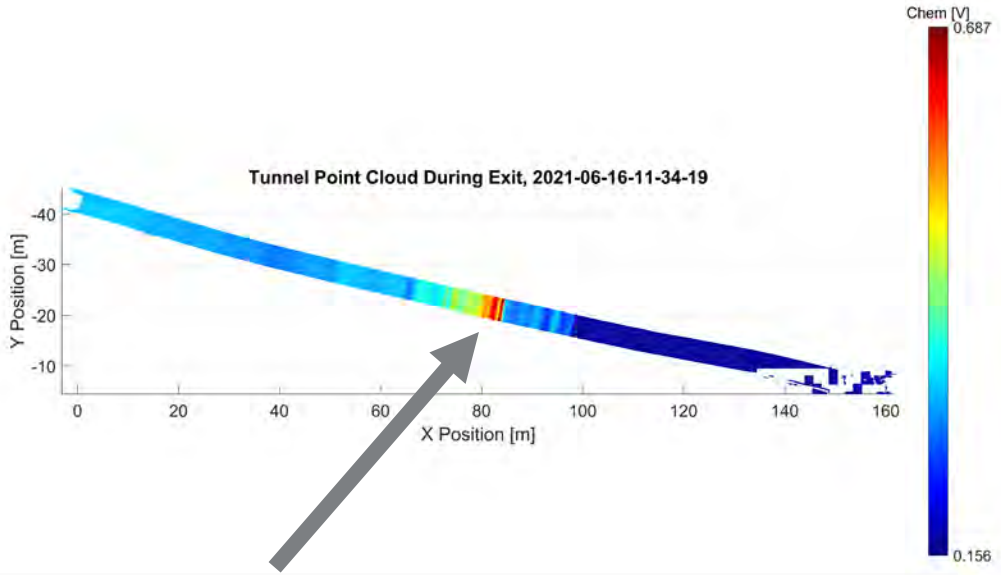
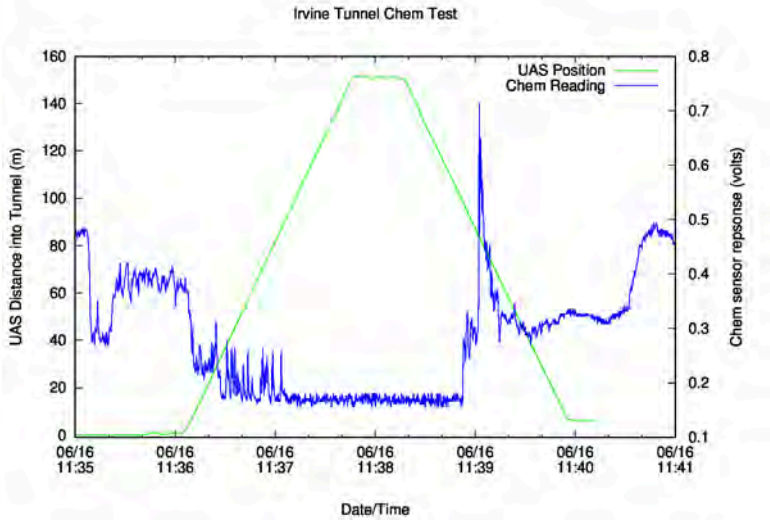
# Results

The chem signal was generally small but distinct.



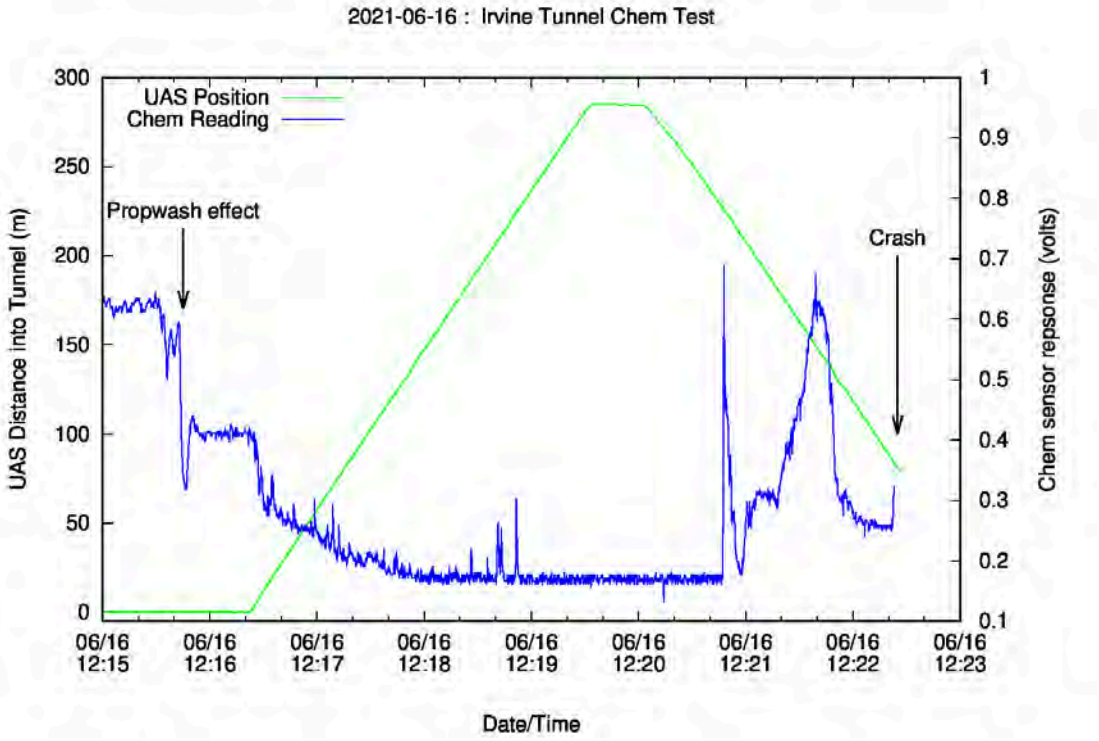




Chemical Spike near Acetone location

We have videos of the flights showing chemical sensor display and also an eerie GoPro video from the rover of the hexacopter flyover.

(Too bad Webex has trouble with videos; contact Rusty if interested.)

# Results




- The chem sensor signals were asymmetric for entering vs. exiting tunnel.
- Prop wash effect and wind direction seemed to favor downwind travel.
- Tunnel also seemed to have its own source of VOC during at least one flight.

# Summary of Results, Path Forward



- The Irvine tunnel is a convenient place to work, but it is not a controlled environment, because there are preexisting chemical signals in that urban tunnel. Consequently, the chemical plume mapping work is subject to several uncertainties.

- The CACTF tunnel at Camp Roberts is a controlled environment (there being no chemical signals except our own); however, it is a much smaller tunnel at 4 feet in diameter.

- The smaller tunnel creates new challenges in flight dynamics, such as the ground effect being constantly present and coming from all directions. Because of this, the folks at OKSI say they need more time to work the problem. We are looking at possibly a JIFX event in May 2022.

- For the Nov. 2021 JIFX event, we are now planning the “Drop from the Mothership” demonstration with our USI collaborators. This will be the aerial deployment of a small drone from a larger drone several miles downrange with data telemetered back to the GS via the larger drone.

# Impact



- A smaller quadcopter navigating a 4-foot diameter tunnel is the next challenge, with a demonstration at the CACTF during a spring or summer JIFX event in 2022.
- Mesh network communications in a tunnel environment are not fully worked out yet, but they will be soon.
- We would also like to do a realistic radiation detection/mapping test in a tunnel (administratively, this may be quite a challenge at JIFX).
- The upcoming “Drop from the Mothership” demonstration involves several operational protocol, communications, and control issues for autonomous and fly-by-wire flights.
- We plan to publish results at MSS and/or SPIE.