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Drone Video Platform—Collision Avoidance, Situational Awareness, and Communications

STL-039-17, Year 1 of 2

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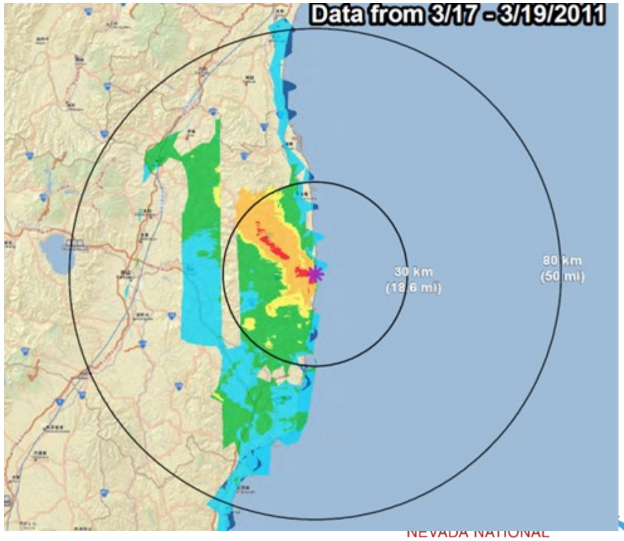
Mission

- In July, 2016, an SDRD deep dive resulted in a proposed mission—to develop and operate within two years a UAS with detectors, returning actionable data, demonstrating the ability to respond to a complex radiological disaster. The UAS was proposed to
  - Fly low and slow to allow for radiological detection, but above or around obstacles;
  - Fly on autopilot using baseline maps with pre-incident geometries;
  - Carry a sensor suite to allow navigation in post-incident geometries;
  - Include on-board processing and algorithms for employing sensor data to react intelligently to unexpected static obstacles;
  - Incorporate a flexible sensor suite for reporting on parameters of concern, especially, but not limited to, radiological hazards; and
  - Include a developed infrastructure for standardization, flexibility, and incorporation of new detectors, and that is simple and standardized for non-expert users.
- When we get the call, can we respond quickly and effectively?

Leveraging Previous Investments

- Previous SDRD
  - Developed platform capabilities
  - Conducted testing with radiological sensors
  - Conducted tests with chemical sensors
- NSTec expertise
  - AMS experience
  - Radiological modeling
- We are expanding on our work with a relevant infrastructure for rapid
  - Response future missions
  - Test bed capability



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Tasks

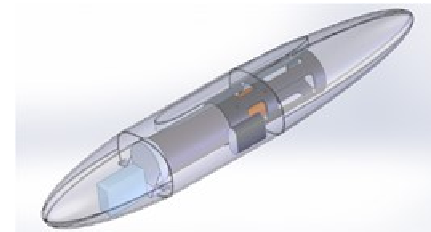
- Year 1
  - Analysis and technology search
  - Develop ICD and requirements
  - Develop collision avoidance framework
  - Design core module
- Year 2
  - Build and test core module
  - Build and test collision avoidance
  - Integrate on platform
  - Analyze data

Goal: develop modular infrastructure for rapid response to disasters and for test bed for sensor systems

SDRD UAS Detector Packages Prepared at STL

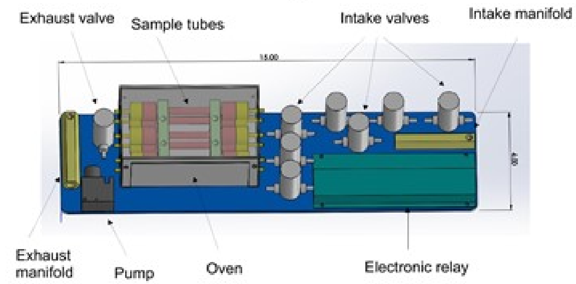
(1) 3×6 NaI(Tl) gamma detector (flown in Feb. and Mar. 2017)

- 695 ml active detector volume
- 7% gamma energy resolution
- Higher sensitivity than Apollo
- For rad surveys and hot spot localizing



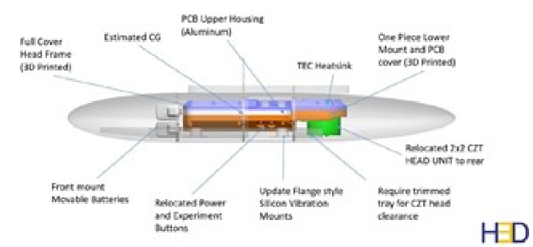
(2) Chemical sensor and sampler (flown in Aug. 2017):

- Real-time volatile organic compound (VOC) sensor
- 6 sampling tubes for post-flight mass spectrometry
- On-runway post-flight chemical analysis via Sionex unit



(3) H3D Apollo detector (to be flown in Sept. 2017):

- 4 CZT crystals 20 × 20 × 15 mm
- 24 ml active detector volume
- 1% gamma energy resolution
- Gamma directional and imaging capability



(4) 2×2 NaI:Tl gamma detector on 3DR Solo Quadcopter (flown without data collect in Aug. 2017):

- 103 ml active detector volume
- 6.5% gamma energy resolution
- Ability to hover in place (or land) and integrate signal

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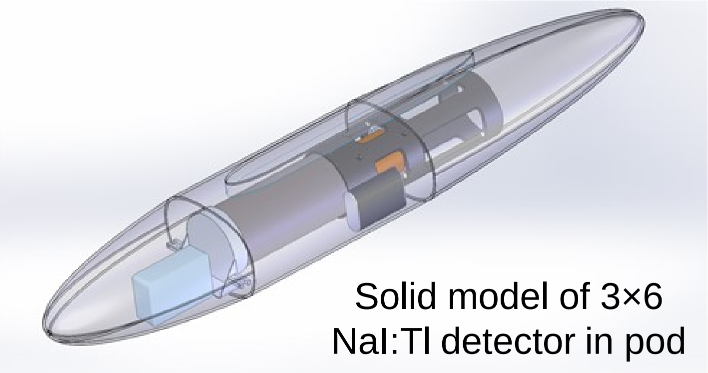
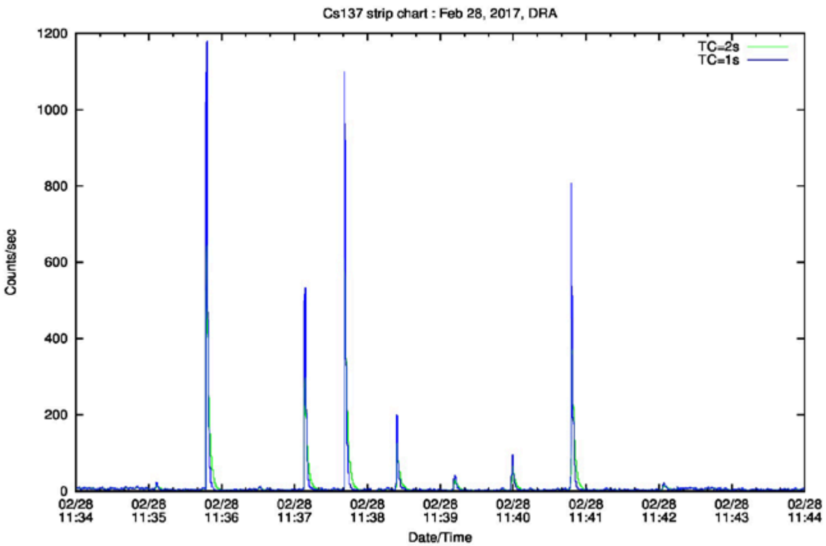
Sandstorm and Detector Pod

3×6 NaI:Tl detector going into pod

Sandstorm on the right with pod



Solid model of 3×6 NaI:Tl detector in pod



Example data; Feb. 28, 2017; two 50 mCi ^{137}Cs sources side-by-side

- Real-time spectral strip chart recorders for 662 keV confirmed that the source was ^{137}Cs
- Seven radiation hits were recorded from the air. One below-threshold hit seen at 11:36:30
- Two small radiation hits appeared during take-off and landing (11:35:07 and 11:42:04)

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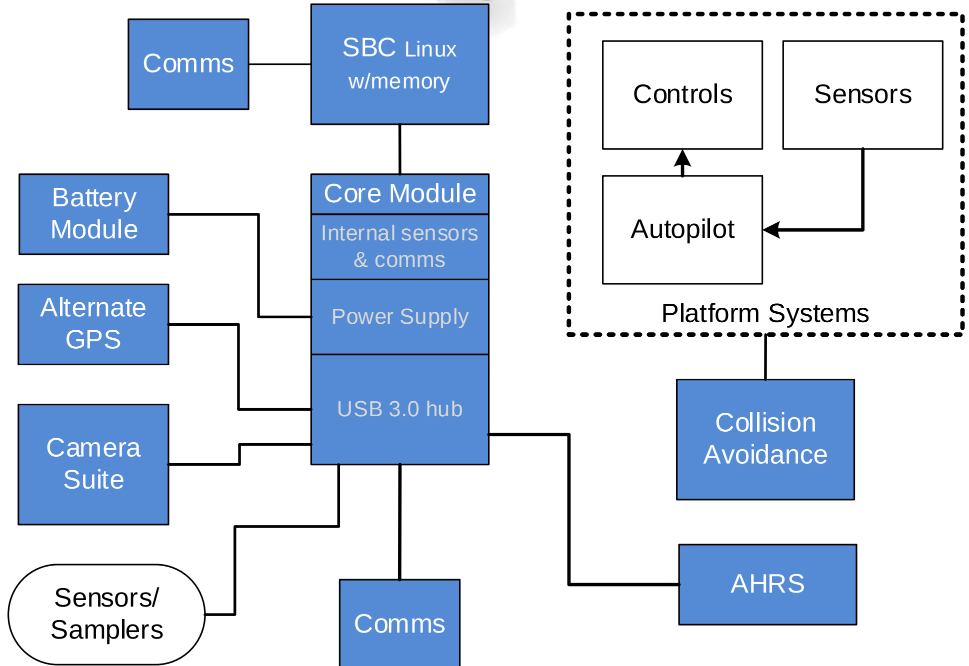
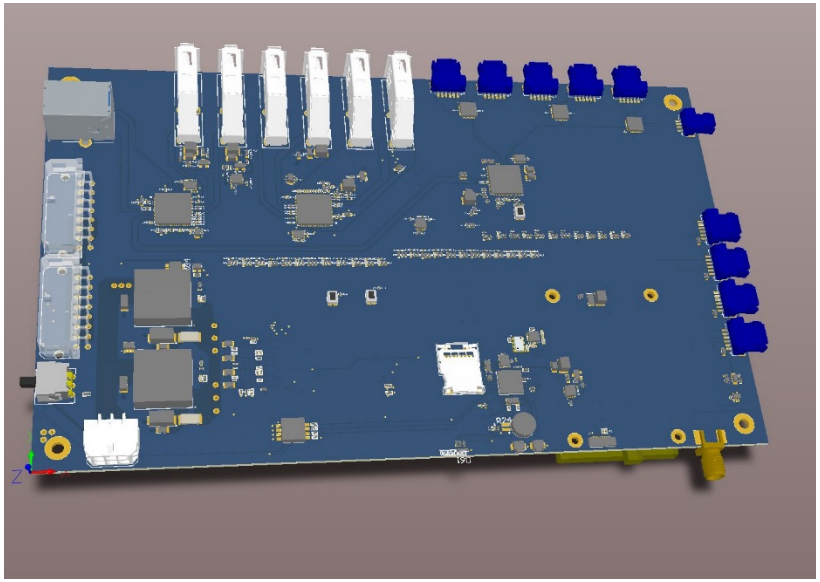
Modular Architecture

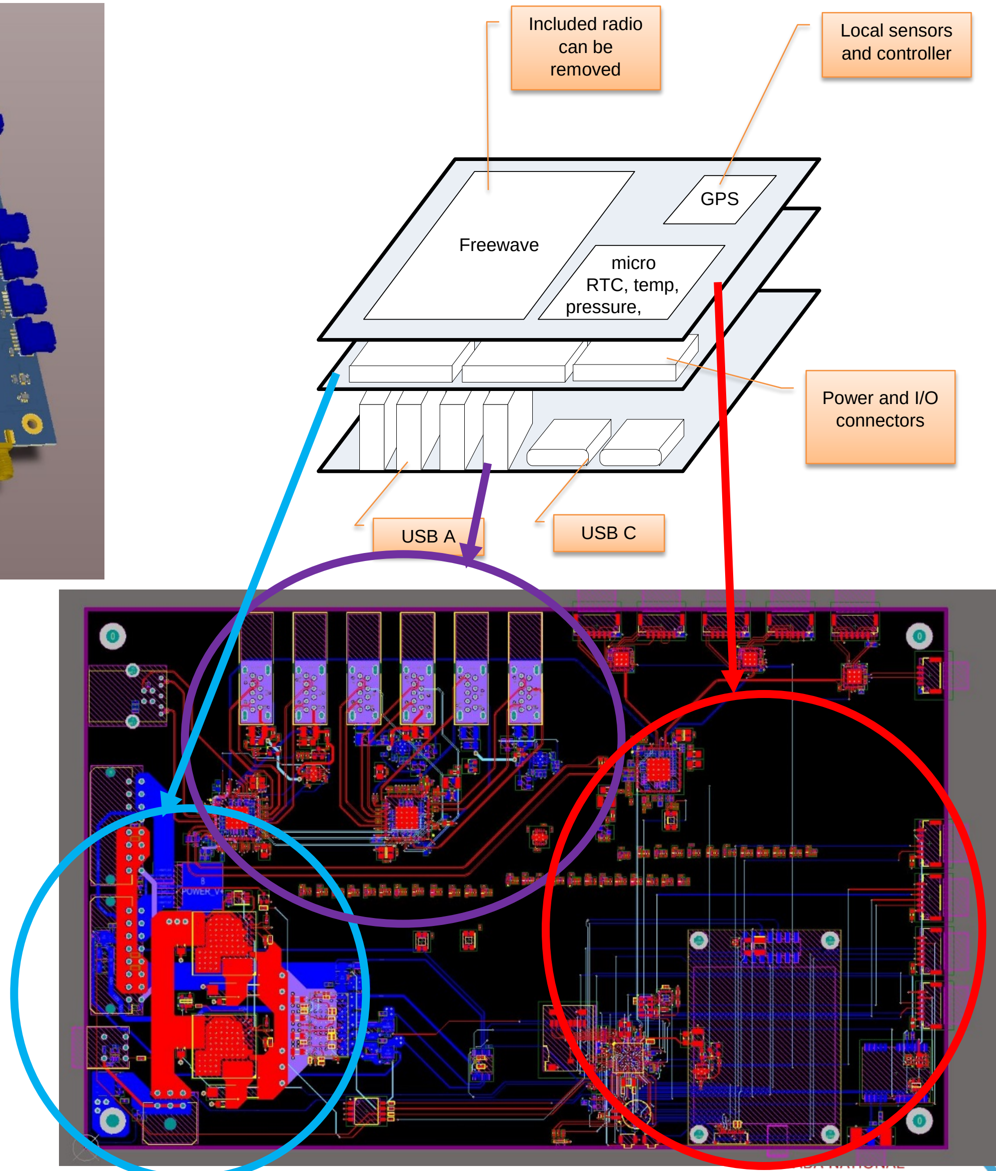
- Modularity allows
  - Quick transition to new platforms
  - Rapid addition of new sensors
  - Ability to quickly test concepts making our UASs ideal test beds
- ICD was developed to identify subsystems and interfaces
  - Requirements are being developed separately
  - Separate from platform-specific systems
- The core module provides
  - Common set of interfaces for the various UAS systems, sensors, peripherals and power.
  - 12V, 5V, 3.3V and raw battery voltage to any system that requires power
  - 6 USB ports and at least two each I2C, SPI, and UART interfaces to be used by any subsystem, sensor or peripheral

- Optional single-board computers allows running of more complex sensor and video algorithms, data aggregation, and real-time data stream compression



Core Module Prototype





- Prototype design on 8″ × 5″ single board
- Parts have been purchased
- Suitable for Sandstorm
- Question on use of proprietary Piccolo autopilot may impact some interfaces
- Worked stopped due to funding

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Batteries and Power Budget

- Power budgets vary depending on mission requirements
- Estimates below are conservative
- Allows for expanded capabilities without power system redesign
- Battery packs made up of 18650 Li-Ion cell batteries; 18 by 6.5 mm
- Several prebuilt sizes with added standard connector for various power and weight needs

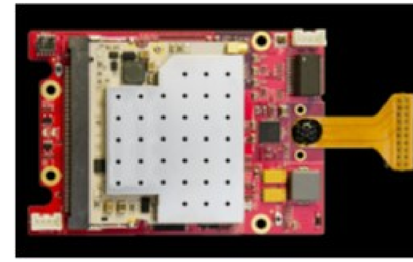
Subsystem	Current at 5 V	Current at 3.3 V	Current at 12 V	System power need (W)
Core module	0.05	0.11		0.613
AHRS		0.25		0.825
Collision avoidance		5		16.5
Cameras	1.2			6
Communications			0.35	4.2
Rad sensors	0.32			1.6
CPU modules	1			5
Chem sensors	0.4			2
Subtotal Total nom (I)	2.97	5.36	0.35	
85% PS efficiency	0.4455	0.804	0.0525	
Total nom (I)	3.4155	6.164	0.4025	
Total nom (W)	17.0775	30.82	2.0125	49.91

AAA 18650

In this scenario, if all systems were on, power draw could be about 50 W

Communications and Cameras

- Communications
  - Modular design allows multiple mission and flight range scenarios
  - Radios may be disabled or not installed per scenario
  - A low data rate (100 Kbps) and long-range data radio by Freewave Technologies will be mounted to the core module
  - For other missions cellular or long-range radios can be added
  - All data will be transmitted encrypted
- Cameras for situational awareness
  - Initial system will use COTS cameras
  - VIOOA provides 360x180° coverage without a gimbal



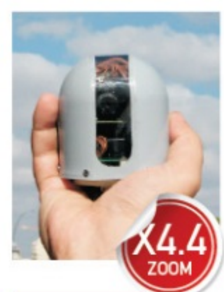
WaveRelay

Cellular sticks

Freewave MM2

Samsung Gear 360 SM-C200

180g 100uRad



115g 100uRad

Virtual gimbal camera - VIOOA for drones (176 g)

Collision Avoidance

- MATLAB model developed to determine how well we can ‘size up’ based on system maneuverability
- Systems for rotary wing platforms exist, but these are not adaptable to the Sandstorm, as fixed-wing aircraft cannot hover and fly at greater speeds
- Two promising technologies are already available, MIT CSAIL and OKSI
- Our system builds directly from Dr. Barry’s MIT CSAIL research
  - Substitute parts selected
  - Platforms assembled
  - Download and installation of many ‘packages’ in process
  - Partial compile of software complete
- After successful testing, this system will be incorporated in the Sandstorm platform

Hobby King FPV platform for initial testing 33.9″ wing span

Imaging Source 160 fps cameras

ODroid XU4 processor

Initial work setting up ODroid SBCs is continuing

SDRD Summary

- This SDRD provides the modular situational awareness and communications infrastructure required to support this mission
  - Allows plug-and-play of DOE-specific sensors
  - Creates a test bed for other sensors
  - Eliminates many integration issues due to comms and cameras being modules with established interfaces and capabilities
- Driven by the need to operate UAVs with a CBRNE detectors that return actionable data. Requires the ability to
  - Avoid post disaster hazards
  - Communicate pertinent information to those on the ground
- Optional modules permit additional sensors or mapping capability
- Leverages existing standard comms and video interfaces, following the interface control document (ICD) defined by the SDRD

FY18 Plans

FY 2018 SDRD will

- Complete infrastructure
  - Fab and test core module
  - Complete assembly and test of collision avoidance on separate platform
  - Integrate and test on relevant platform
- Conduct experimentation
  - Modular system testing
  - Optical/gamma data fusion
  - Autonomous execution
  - Autonomous systems collaboration