Multi-modal Global Surveillance Science and Technology for Predictive and On-demand Characterization of Localized Processes Using Cube Satellite Platforms

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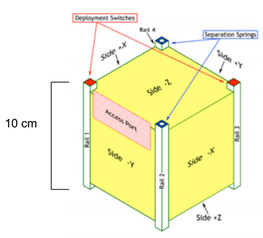
ETI 2019 ANNUAL WORKSHOP NOVEMBER 5-6, 2019

Project Description

- Cube satellites (CubeSats) provide a unique platform for monitoring of localized processes anywhere within the planet surface or atmospheric layers.
- Areas of interest can be targeted at times of interest periodically or on-demand
- CubeSats equipped with sensors and data analytics provide novel surveillance technology
  - Autonomy
  - Global Reach
  - Self-protection
- Integrated program consisting of computational and experimental elements
  - Development
  - Design
  - Analysis
- Lead to prototype design of a system to be launched from the International Space Station (ISS) using Nanoracks platforms

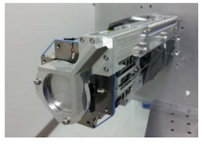
CubeSat Architecture

- CubeSats are measured in units of U, 1U is equal to 10 cm x 10 cm x 10 cm cube with a mass close to 1 kg
- Sizes range from 1U to 12U
- Most likely size for including a high-resolution sensor is 3U



Sensors

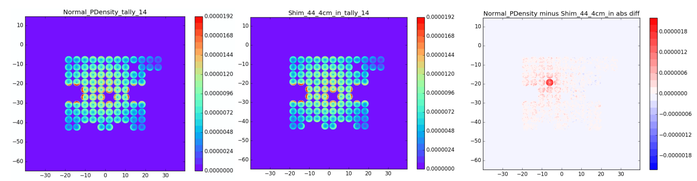
- Must optimize for a high-resolution imaging sensor
  - Images will be taken from the atmosphere at about 500-700 km from surface
  - Image resolution needs to be at about 1 m
  - Must fit within specifications of CubeSat volume (~3U)
  - Example:
    - Deployable Petal Telescope
- CubeSat system could also possibly include biosensors for radiation sensibility at large distances



Data Analysis and Reconstruction Methods

- Development and use of analytic technologies including fusion (spatial and spectral analysis) and machine learning to facilitate prediction and characterization
- Must allow for automation of CubeSat surveillance system
- Must allow for image recognition and processing
- Must deal with data and memory management feasibly due to the large sizes of the high-resolution images
- Using differences in data to detect changes
  - Detection of small control rod movement in core
  - Small changes in radiation signatures could flag areas of potential interest in satellite data
  - Otherwise unnoticeable perturbations become clear

Baseline | Rod Shifted | Difference

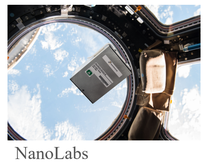


Future Demonstrations

- CubeSat-based survey method will be demonstrated using available high-resolution imagery
- Multi-modal spectral interrogation based on high-resolution remote sensing will yield unique signatures for characterization and demonstration
- Demonstrations will include
  - Aerial phenomena
  - Simulated fuel cycle facilities
  - Other surface and atmospheric phenomena

Nanoracks

NanoRacks External Platform (NREP)



NanoLabs

Plate Reader-2

NanoRacks CubeSate Deployer (NRCSD)

External Cygnus

Kaber

Task 1: CubeSat-based global surveyor architecture development

- 1.1. CubeSat configuration and platform capabilities
- 1.2. Instrumentation options analysis for CubeSat based surface and atmospheric surveys
- 1.3. Enabling data analysis methods to support data fusion, reconstruction, and predictive analysis
- 1.4. Multi-modal signature development accounting for high resolution remote sensing data streams
- **1.5. Prototype concept and computational analysis to demonstrate capability***

Task 2: Specification development for a CubeSat-based global surveyor*

- 2.1. CubeSat very high-resolution sensing options with focus on optical image analysis, reconstruction and signature development
- 2.2. Multi-modal spectral signature analysis options in CubeSat architectures
- 2.3. Hardware specification development and integration options analysis

*Deliverable

Task 3: Computational and experimental program based on surrogate and simulated data sets demonstrating capabilities of the proposed orbital surveyor platform*

- 3.1. 3D surface and atmospheric mapping method with dynamic feature localization and analysis
- 3.2. CubeSat surveyor performance model and data simulation
- 3.3. Data analytics demonstration program based on high-resolution multi-modal signatures (land and atmospheric mapping, feature extraction, object recognition) – human activity localization, activity detection and interpretation with resolutions higher than 5m

Task 4: CubeSat design and data analysis towards a future demonstration launch program

- 4.1. Data analysis and data acquisition system development and specification in support of the CubeSat surveyor architectures
- 4.2. Data analytics methods including fusion (spatial, spectral, scale-space adaptations) and machine learning based on CubeSat data streams
- 4.3. Design of a cube-satellite-based global surveyor and the launch program development

Task Timeline

Task	Year 1				Year 2				Year 3				Year 4				Year 5			
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
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Outcomes

- The proposed effort is focused on science and technology of predictive and on-demand characterization of localized developments on the earth surface, subsurface and within atmosphere.
- The use of orbital survey methods offers access options for any location in 3D from subsurface up to upper atmosphere, continuously and over discrete periods of interest.
- The project is a synthesis of high TRL observational platforms (CubeSats) with lower TRL sensors and predictive methods including fusion and machine learning to yield a robust multi-modal surveillance and prediction capability.
- The CubeSat surveyor solves the challenge of access to the location of interest. **The process signature development is an integral part of the effort.** The results will be widely applicably for all survey programs where signatures are needed to characterize developing local phenomena remotely.

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