# A Bimodal 3U-CubeSat Mission to Measure the Effects of Solar Particle Events on the Earth's Atmosphere

CubeSat Developers Workshop - April 25, 2023


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*Advisor: Dr. Peter Englert*

# EPET (Earth and Planetary Exploration Technology)

**EPET 201: Space Exploration**

Earth and Planetary Exploration Technology (EPET) Certificate

B.S. Mechanical Engineering concentration in Aerospace Engineering

**EPET 301: Space Science & Instrumentation**

**Hawai’i Space Grant Consortium & UROP Funding**

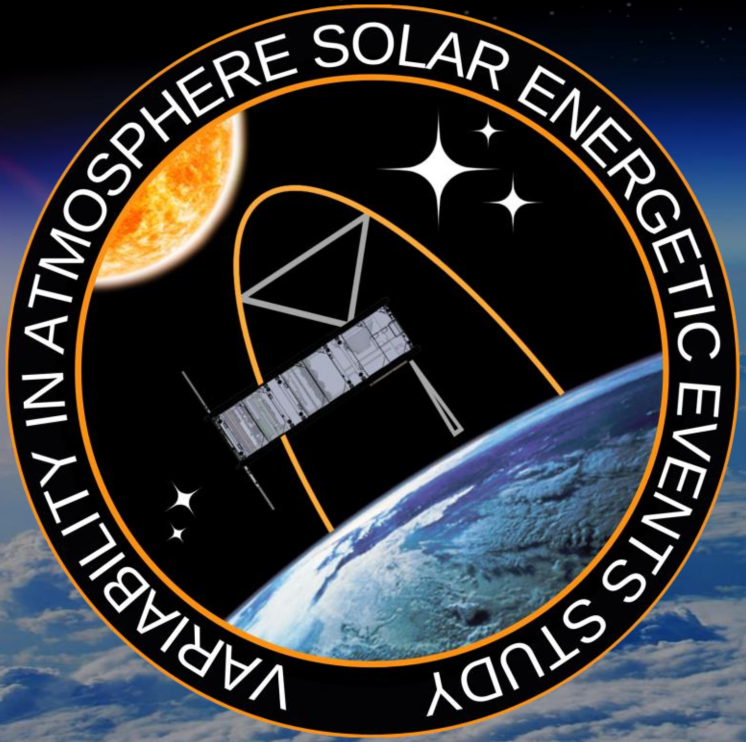
**EPET 400: Space Mission Design**

**Payload Design & Development NASA CSLI Proposal**

**EPET 401: Capstone Project**

**Payload Procurement & Production**

# Introduction

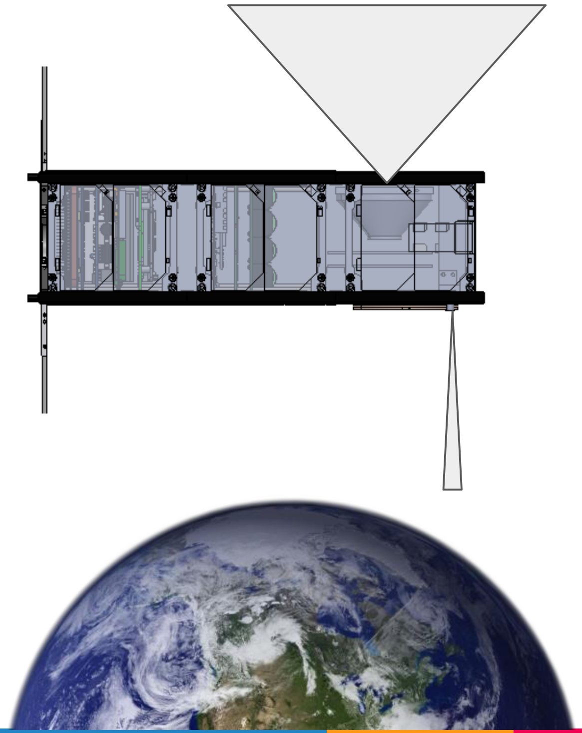



VIA-SEEs aims to address key knowledge gaps as NASA has defined across multiple decadals and the NASA Heliophysics Roadmap (2014-2033) which states that understanding Earth's atmospheric response to auroral, radiation belt, and solar energetic particles in the form of variability in Nitrogen Oxides (NOy) and Ozone ($O_3$), is of a high importance.

While other missions (e.g. AURA, UVSC Pathfinder) have studied Nitrogen Oxides and Ozone, or Solar Energetic Events in Low Earth Orbit (LEO), no mission has yet integrated both into one spacecraft.

# Our Mission

Project VIA-SEEs intends to utilize one 3U CubeSat in Low Earth Orbit (LEO) to measure the direct correlation between Solar Energetic Events and the variabilities in the total reactive Nitrogen Oxides (NOy) and Ozone ($O_3$) concentration in the mesosphere, thereby enhancing our understanding of how our atmosphere changes in response to solar particle radiation.



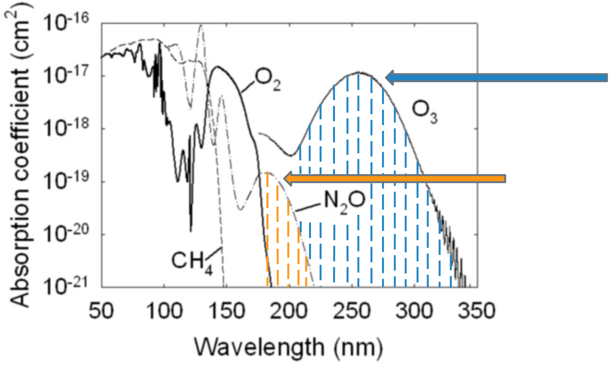
# Variability In Atmosphere (VIA) Detector

Our VIA detector is a COTS CMOS spectrophotometer from AVANTES' Compact line, model AVASpec-Mini2048CL.

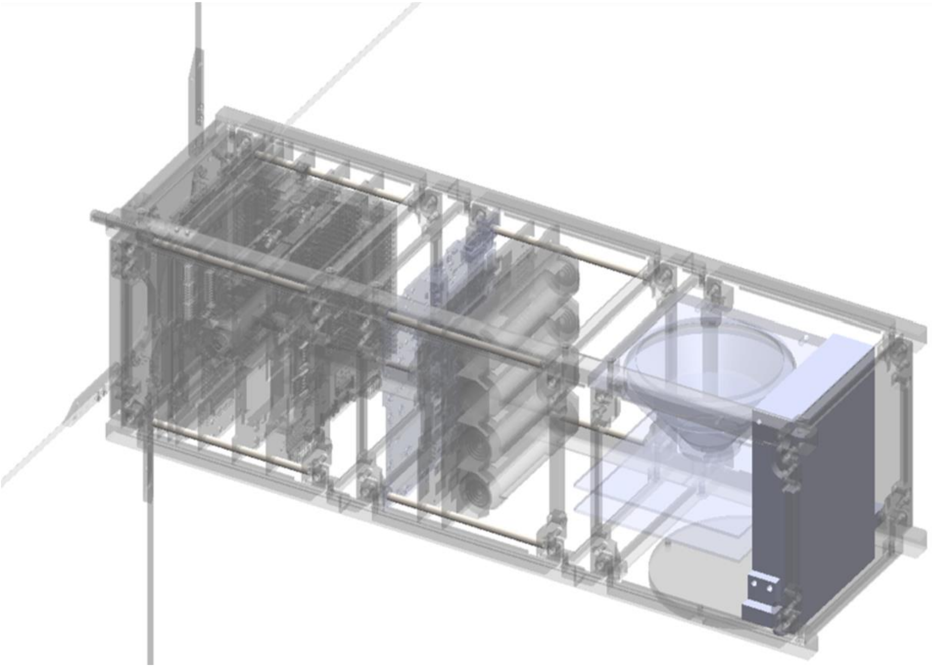
It has flight heritage since 2017.

It can collect spectra within UV and Visible light ranges and is, therefore, able to measure the ozone and nitrous oxide reflectance spectra that we seek surrounding solar energetic events.

An Ocean Insight P400-1-SR fiber optic cable will allow light into the CMOS.

# Variability In Atmosphere (VIA) Detector



**AvaSpec Mini**
**2048CL**
**(VIA)**

The AvaSpec-Mini2048CL spectrometer

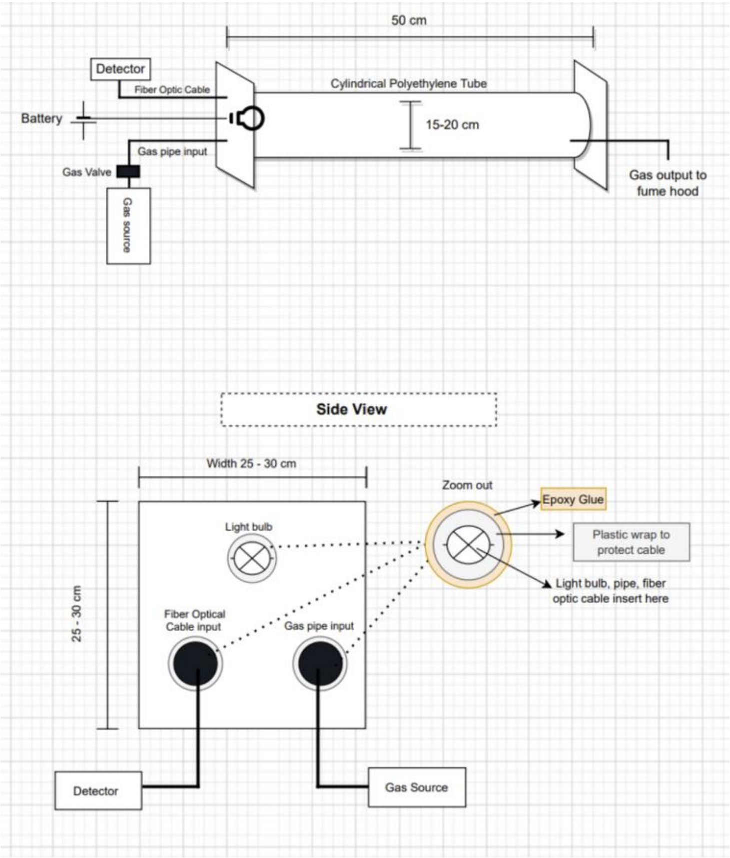
# Variability In Atmosphere (VIA) Calibration and Testing

We are finishing the design of our calibration and testing apparatus

Apparatus will be made of a cylindrical ultra low outgassing polyethylene tube approximately 50 cm long and 15-20 cm in height

Connection points will be sealed with plastic wrap and epoxy glue

We have NO currently being shipped to us, and have recently received a 1KNT Ozone Generator from Oxidation Technologies



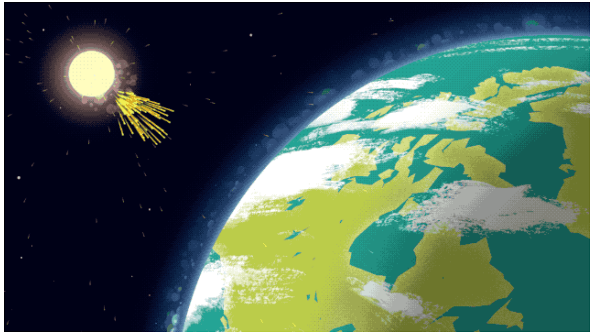
# Solar Energetic Events (SEE) Detector

The SEE detector is a charged-particle energy spectrometer that will measure the energy levels of incident solar energetic particles.

Existing relevant instrumentation include:

- REPTile, charged particle spectrometer, MeV range
- EPT, charged particle spectrometer, keV to MeV range
- ISIS, charged particle spectrometer, keV to MeV range
- SCD, x-ray dispersive spectrometer, high intensity X-rays

However, none of these detectors are suitable for the energy ranges we are interested, nor do they follow bimodal mission operations. Therefore, the SEE detector is being developed in-house.



# Solar Energetic Events (SEE) Detector

The SEE detector consists of a stack of sensors.

When a charged-particle strikes one of these semiconductor wafers, a pulse of current develops

- Electron-hole pair

These pulses are amplified, recorded, and analyzed to determine the energy, quantity, and species of the incident-charged particles.

Adaptive voltage concept

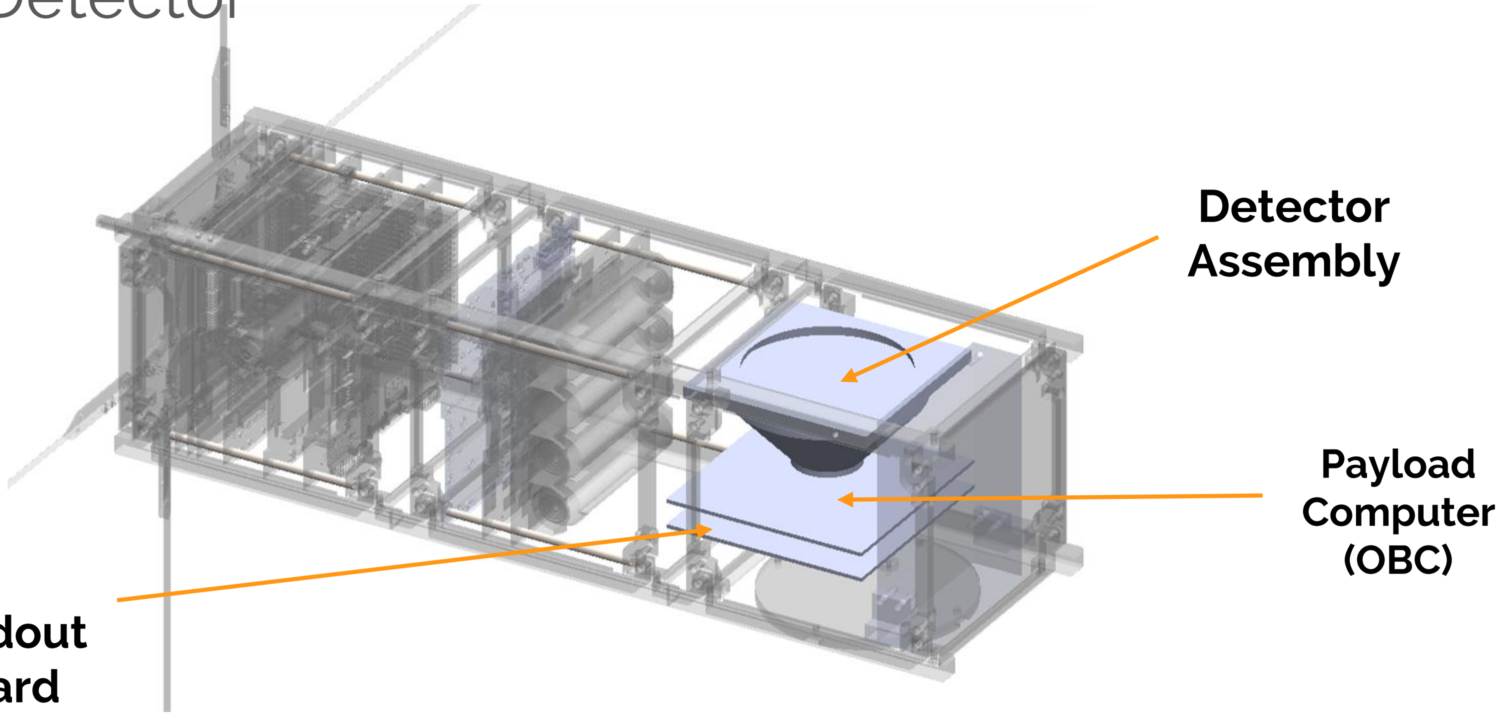
- Improved energy resolution

Detector geometry considerations

- Hour-glass vs cylindrical

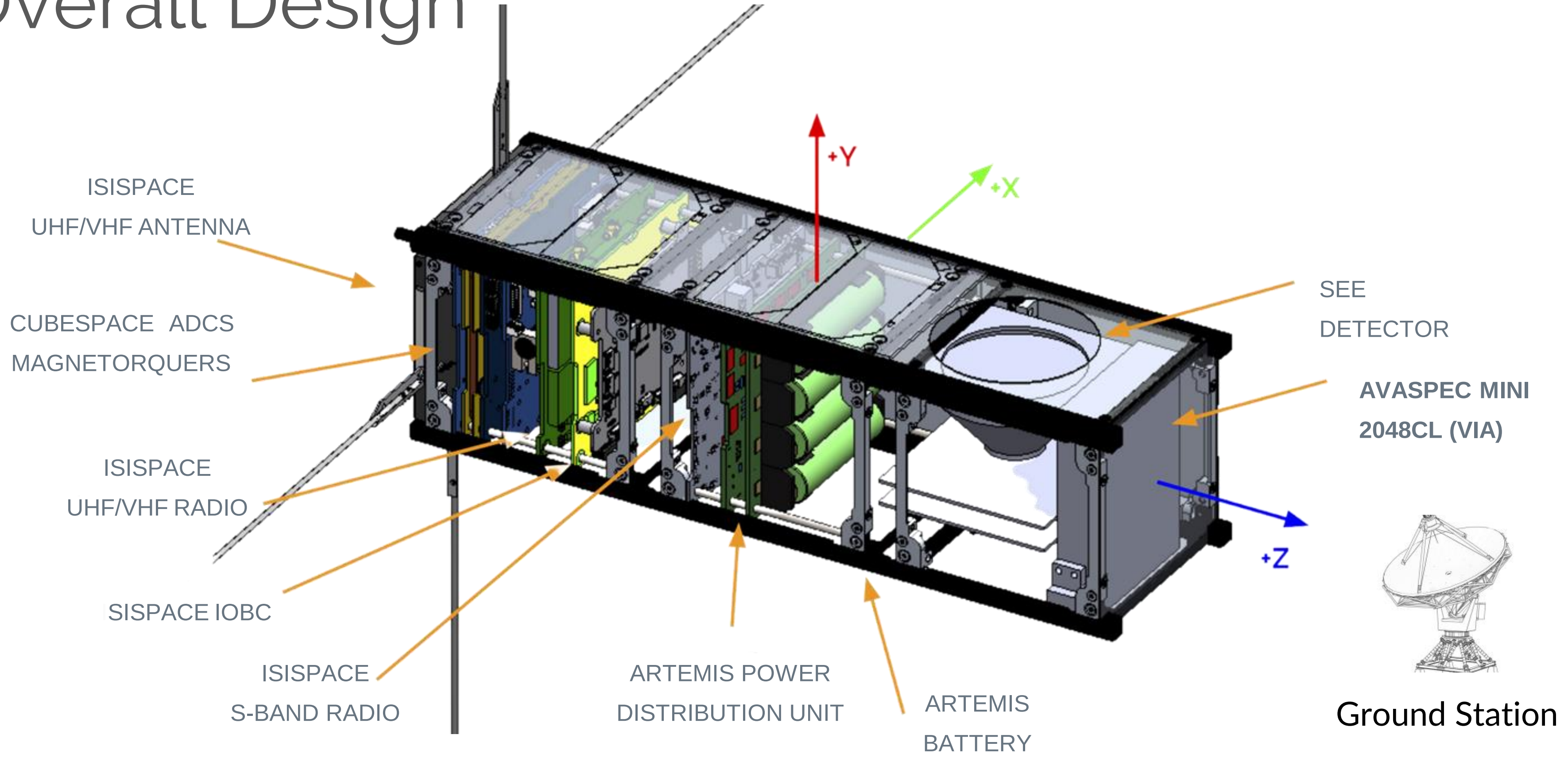
| Detector | Diameter (mm) | Energy of Ionizing Radiation |
|---|---|---|
| Gas Electron Multiplier (GEM) | 75 | Electrons of all energies |
| Silicon (SiC) | 75 | Electrons of 10-300 keV |
| Silicon (Si) | 50 | Electrons of 300-700 keV |
| Germanium (Ge) | 50 | Electrons of 700 - 2,000 keV |
| Germanium (Ge) | 75 | Protons of 2-80 MeV |

# Solar Energetic Events (SEE) Detector




Together, the VIA and the SEE detectors will fit in 1U (10 x 10 x 10 $cm^3$)

# Overall Design



# NASA CSLI Acceptance


VIA-SEEs was 1 of 8 missions selected during the 14th round of NASA's CubeSat Launch Initiative (CSLI)

"Launch opportunities for the selectees are provided through the Educational Launch of Nanosatellites (ELaNa) missions facilitated by NASA's Launch Services Program (LSP). "

# References

Heliophysics Roadmap Team, Nasa Advisory Council. Heliophysics Subcommittee, & National Aeronautics And Space Administration. (2009). Heliophysics: the solar and space physics of a new era: a recommended roadmap for science and technology 2009-2030: 2009 Heliophysics Roadmap Team report to the NASA Advisory Council Heliophysics Subcommittee, May 2009. National Technical Information Services.

Mitsunori Ozaki, Kazuo Shiokawa, Ryuho Kataoka, Martin Mlynczak, Larry Paxton, Martin Connors, Satoshi Yagitani, Shion Hashimoto, Yuichi Otsuka, Satoshi Nakahira, Ian Mann, "Localized Mesospheric Ozone Destruction Corresponding to Isolated Proton Aurora Coming From Earth's Radiation Belt", Scientific Reports, 2022.

Our Dynamic Space Environment: Heliophysics Science and Technology Roadmap for 2014-2033.

Schiller, Q. G., Mahendrakumar, A., & Li, X. (2012, June). REPTile: A Miniaturized Detector for a CubeSat Mission to Measure Relativistic Particles in Near-Earth Space.

Segura, Antígona, et al. "Biosignatures from Earth-like Planets around M Dwarfs." Astrobiology, vol. 5, no. 6, 2005, pp. 706–725., https://doi.org/10.1089/ast.2005.5.706.

Van Allen, James, Louis Frank, "Radiation Around the Earth to a Radial Distance of 107,400km", Nature, Vol. 183, February 14th, 1959.

# Mahalo!
# Questions?


**Acknowledgements**

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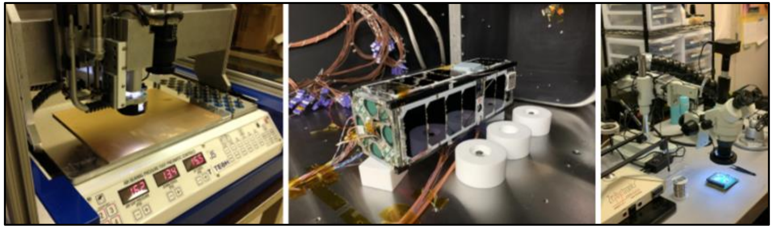
Amber Imai-Hong
Hawaii Space Grant Consortium
Hawaii Space Flight Laboratory

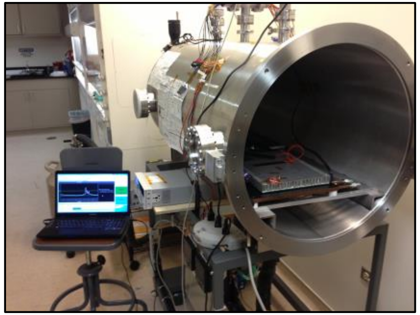
# Integration & Test Equipment

**Intlvac Thermal Vacuum Chamber**
1.6 m I.D. x 2.25 m long, $10^{-8}$ Torr

**Attitude Control Test Facility**
ADCS testing for 1-100 kg satellites



**Spacecraft Avionics Development Equipment/Facilities**
Machine Shop, PCB prototyping and repair equipment, etc.



**Lesker Thermal Vacuum Chamber**
0.6 m I.D. x 1.2m long, $10^{-6}$ Torr

**Vibration and Shock Table**
Tests objects 1.2 x 1.2m
5-2200 Hz to 7000 kgf; 14000 kgf shock

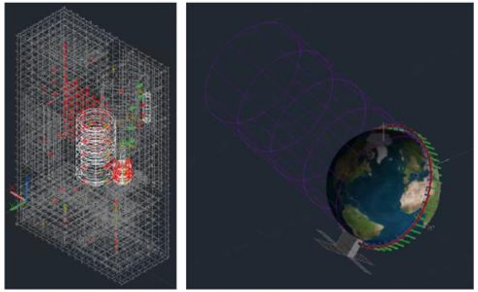
**Class 10,000 (ISO 7) cleanroom**
Located in the basement of the POST building.

# Overview of Capabilities

**Intlvac Thermal Vacuum Chamber**
1.6 m I.D. x 2.25 m long, $10^{-8}$ Torr

**Attitude Control Test Facility**
ADCS testing for 1-100 kg satellites
Magnetic Field, Sun, Nadir, GPS and Star tracker stimulators

HSFL engineers working on HiakaSat-1

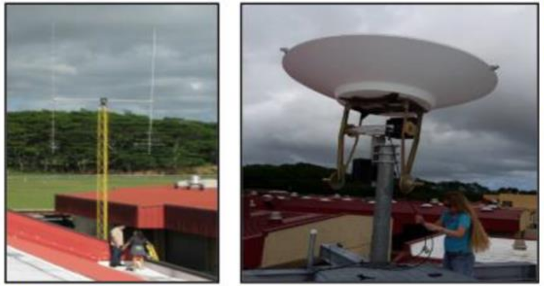


Thermal and orbital modelling capabilities

**Vibration and Shock Table**
Tests objects 1.2 x 1.2m
5-2200 Hz to 7000 kgf; 14000 kgf shock

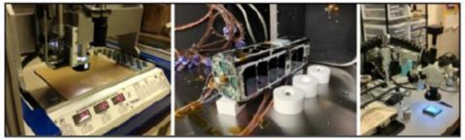
**Spin Balancer**

**Class 10,000 cleanroom**
Located in the basement of the POST building.



HSFL UHF/VHF/S-band ground receiving stations

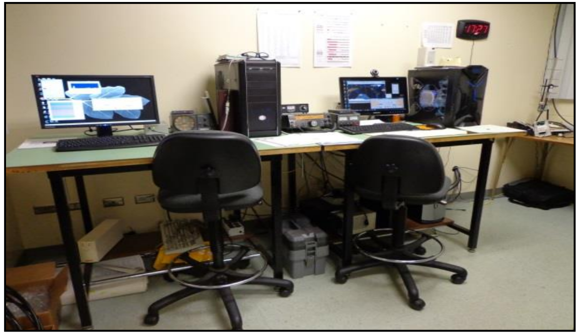
HSFL led the development of the ORS-4 Super-Strypi launch vehicle



**Spacecraft Avionics Development Equipment/Facilities**
Machine Shop, PCB prototyping and repair equipment, etc.

# HSFL Ground Stations

Honolulu Community College
X-band



Kauai Community College
UHF/VHF/S-band

**Affiliated Ground Stations:**
Alaska Space Facility (S-band)
Surrey Space Centre/SSTL (UHF/VHF/S-band)

UH Manoa – NRL MC3 GS
UHF/S-band

# Variability In Atmosphere (VIA) Gantt Chart

## GANTT CHART FOR VIA

| | TASK | START | END | 2022 | | | | | | 2023 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DATE | DATE | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
| 2022 | Spectrometer Trade Study | 7/11/2022 | 8/20/2022 | | | | | | | | | | | | | | | | | | |
| | Purchase Spectrometer & Fiber Optic Cable | 8/20/2022 | 8/15/2022 | | | | | | | | | | | | | | | | | | |
| S23 | Connect Spectrometer to OBC | 1/9/2023 | 1/23/2022 | | | | | | | | | | | | | | | | | | |
| | Write Test Code Via Python; Serial Communication | 1/24/2023 | 2/24/2023 | | | | | | | | | | | | | | | | | | |
| | Simulated Atmosphere Tests | 2/25/2023 | 5/12/2023 | | | | | | | | | | | | | | | | | | |
| FALL 2023 | Develop Testbed | 8/28/2023 | 9/12/2023 | | | | | | | | | | | | | | | | | | |
| | Thermal Vacuum Tests | 9/13/2023 | 9/27/2023 | | | | | | | | | | | | | | | | | | |
| | Vibration Chamber Tests | 9/28/2023 | 10/31/2023 | | | | | | | | | | | | | | | | | | |
| | Testing with Radiation Source | 11/1/2023 | 11/20/2023 | | | | | | | | | | | | | | | | | | |
| | Instrument Flight Validation | 11/21/2023 | 12/16/2023 | | | | | | | | | | | | | | | | | | |

| | |
|---|---|
| | Summer & Fall 2022 |
| | Spring 2023 |
| | Fall 2023 |

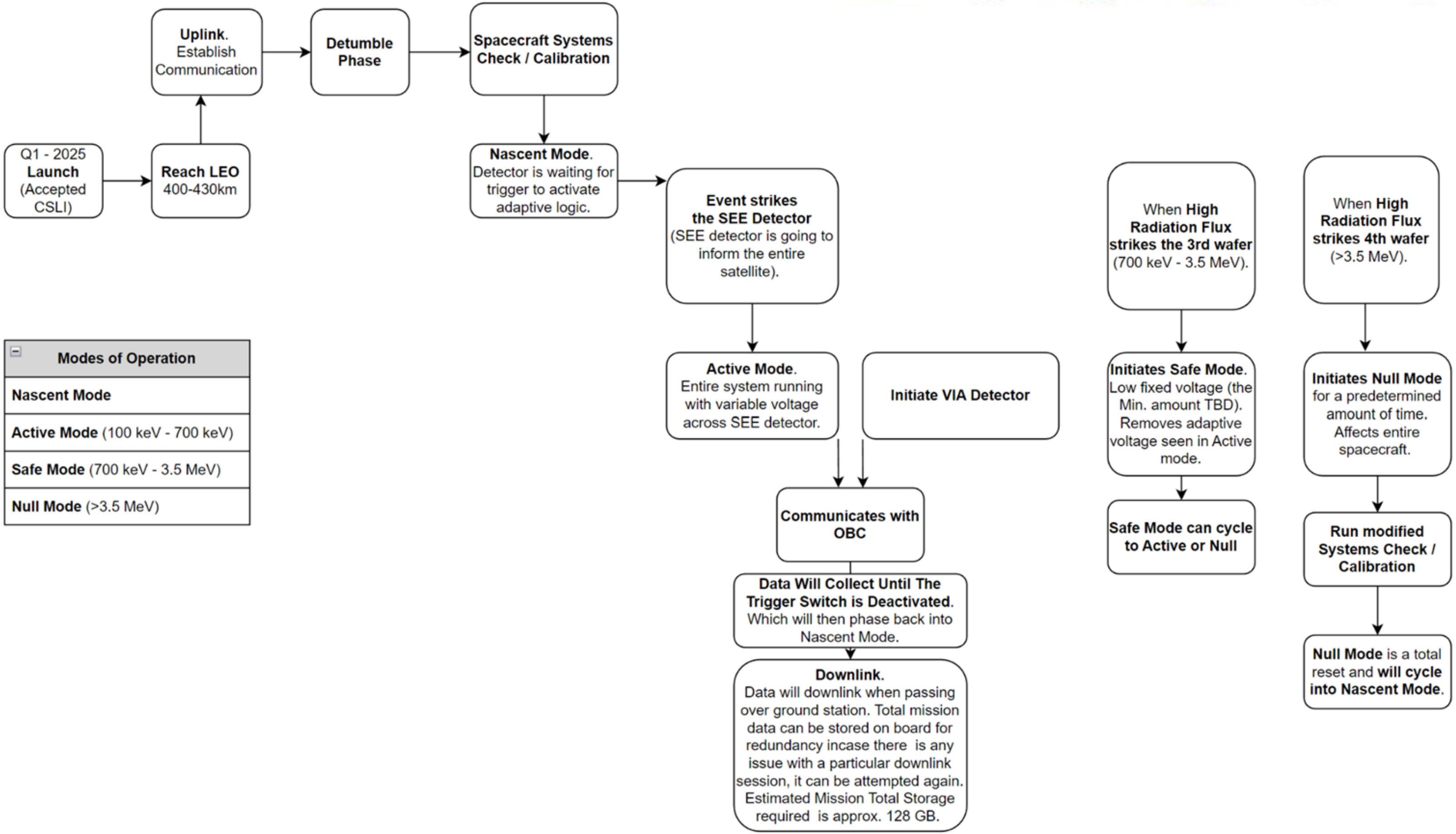
# Solar Energetic Events (SEES) Detector

## GANTT CHART FOR SEE

| | TASK | START DATE | END DATE | 2022 J | A | S | O | N | D | 2023 J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2022 | Selection of Detector Prototype | 8/20/2023 | 10/15/2023 | | | | | | | | | | | | | | | | | | |
| | Completion of Detector of CAD Model | 10/15/2023 | 1/31/2023 | | | | | | | | | | | | | | | | | | |
| S23 | Completion of Detector Design | 1/15/2023 | 3/15/2023 | | | | | | | | | | | | | | | | | | |
| | Experimental Testing of Components | 2/15/2023 | 5/15/2023 | | | | | | | | | | | | | | | | | | |
| | Analysis using Geant 4 Simulations | 3/15/2023 | 7/15/2023 | | | | | | | | | | | | | | | | | | |
| | Purchase Materials and Electronics | 4/15/2023 | 8/15/2023 | | | | | | | | | | | | | | | | | | |
| FALL 2023 | Assembly of Components | 7/1/2023 | 8/15/2023 | | | | | | | | | | | | | | | | | | |
| | Detector Calibration | 8/15/2023 | 9/30/2023 | | | | | | | | | | | | | | | | | | |
| | Vibration Chamber Tests | 9/15/2023 | 10/15/2023 | | | | | | | | | | | | | | | | | | |
| | Testing with Radiation Source | 10/1/2023 | 11/30/2023 | | | | | | | | | | | | | | | | | | |
| | Instrument Flight Validation | 11/15/2023 | 12/16/2023 | | | | | | | | | | | | | | | | | | |

| | |
|---|---|
| | Summer & Fall 2022 |
| | Spring 2023 |
| | Summer & Fall 2023 |

# Concept of Operations




| Modes of Operation |
|---|
| **Nascent Mode** |
| **Active Mode** (100 keV - 700 keV) |
| **Safe Mode** (700 keV - 3.5 MeV) |
| **Null Mode** (>3.5 MeV) |

# Mass Budget

| Subsystem | Component | Unit Mass (g) |
|---|---|---|
| Payload | SEE Detector | 1000 |
| | AvaSpec-Mini2048CL | 175 |
| Spacecraft | ISISpace iOBC | 100 |
| | Artemis Battery Pack | 294 |
| | Artemis PDU | 70 |
| | CubeSpace ADCS Magnetic | 225 |
| | ISISpace Solar Panels | 600 |
| | ISISpace 3U Structure | 304.3 |
| | ISISpace VHF/UHF Transceiver | 75 |
| | ISISpace VHF/UHF Antenna | 100 |
| | ISISpace S-Band Transmitter | 120 |
| | ISISpace S-Band Antenna | 50 |
| | Sub Total (g) | 3113.3 |
| | Harnessing (10%) | 311.33 |
| | **Total (g)** | 3424.63 |
| | **Remaining Mass (g), 4.8 kg max** | 1375.37 |

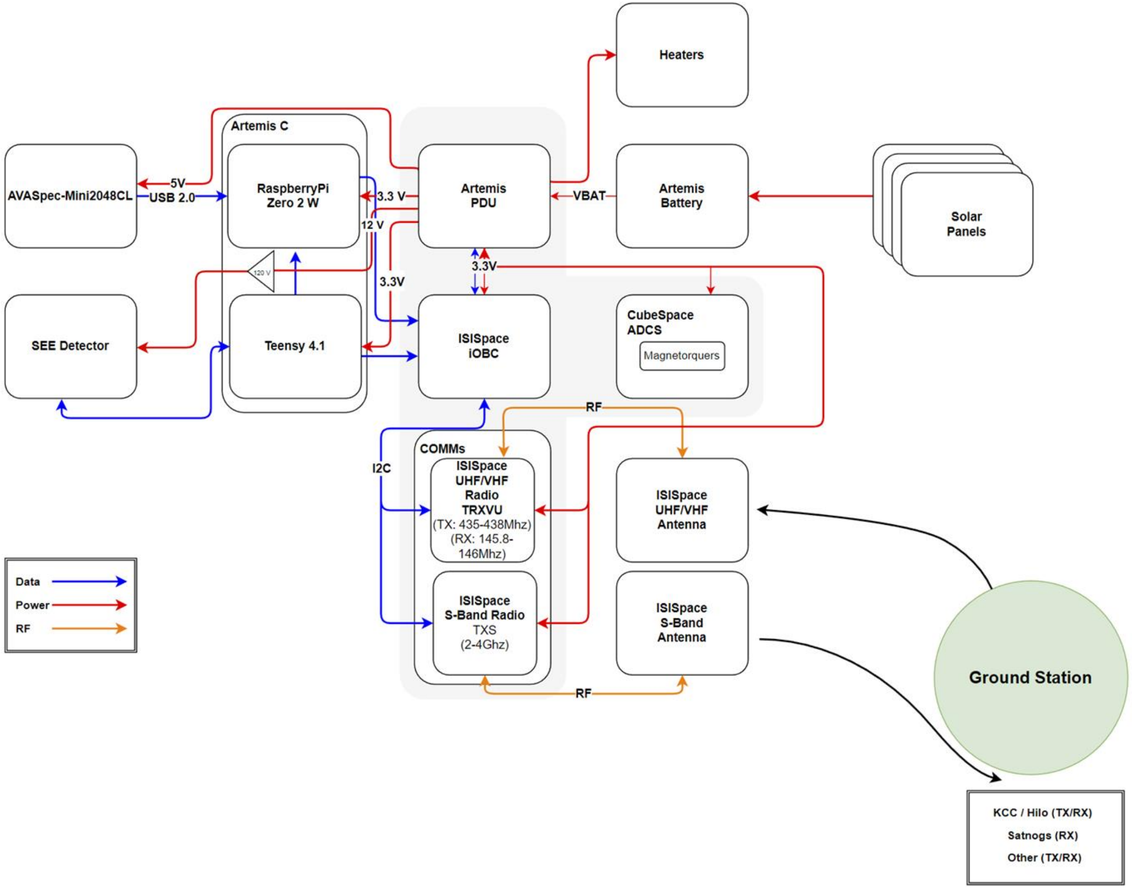
# Power Allocation

| Subsystem | Component | Part Name/Datasheet | By Subsystem | Peak Power Usage | Duration per Orbit | Average Power Consumption per Orbit (Wh) | % of Power Budget |
|---|---|---|---|---|---|---|---|
| | VIA | VIA | | 1.25 | 0.25 | 0.313 | 1.55% |
| Payload | SEE | SEE | 4.66% | 2.5 | 0.25 | 0.625 | 3.11% |
| | Transmitter (TX) | ISISpace S Band Transmitter | | 13 | 1.07 | 13.867 | 68.99% |
| | Reciever (RX) | ISISpace UHF/VHF Transceiver | | 4 | 0.65 | 2.600 | 12.94% |
| COMMs | Deployment | ISISpace UHF/VHF Antenna Deployer | 81.94% | 15 | 0.00 | 0.001 | 0.00% |
| | ISC | Teensy 4.1 | | 2.3 | 0.58 | 1.342 | 6.68% |
| | ISC | Raspberry Pi Zero | | 0.4917 | 0.87 | 0.426 | 2.12% |
| OBC | OBC | ISIS OBC | 9.29% | 0.4 | 0.25 | 0.100 | 0.50% |
| | Gyroscope | | | 0.0052 | 0.33 | 0.002 | 0.01% |
| | Magnetometer | | | 0 | 0.33 | 0.000 | 0.00% |
| | Accelerometer | BMX160 | | 0 | 0.33 | 0.000 | 0.00% |
| | GPS | S1216F8-BD | | 0 | 0.33 | 0.000 | 0.00% |
| ADCS | CubeSpace (Magn | Gen 1 | 2.64% | 1.585 | 0.33 | 0.528 | 2.63% |
| | Heater | KHLVA-0502/(*) | | 5 | 0.00 | 0.000 | 0.00% |
| Thermal | Thermal Sensors x | TMP36F | 0.02% | 0.0035 | 1.07 | 0.004 | 0.02% |
| | Battery Board | PyCubed | | 0 | 0.00 | 0.000 | 0.00% |
| EPS | Distribution Unit | Artemis Design | 1.45% | 0.5 | 0.58 | 0.292 | 1.45% |
| | | | | | | 20.098 | 100.00% |
| | | Mode | Duration [hr] | | | | |
| | | Nominal | 0.5333333333 | | | | |
| | | Pointing | 0.25 | | | | |
| | | Data Collect | 0.25 | | | | |
| | | Data Received | 0.01666666667 | | | | |
| | | Data Transmitted | 0.06666666667 | | | | |

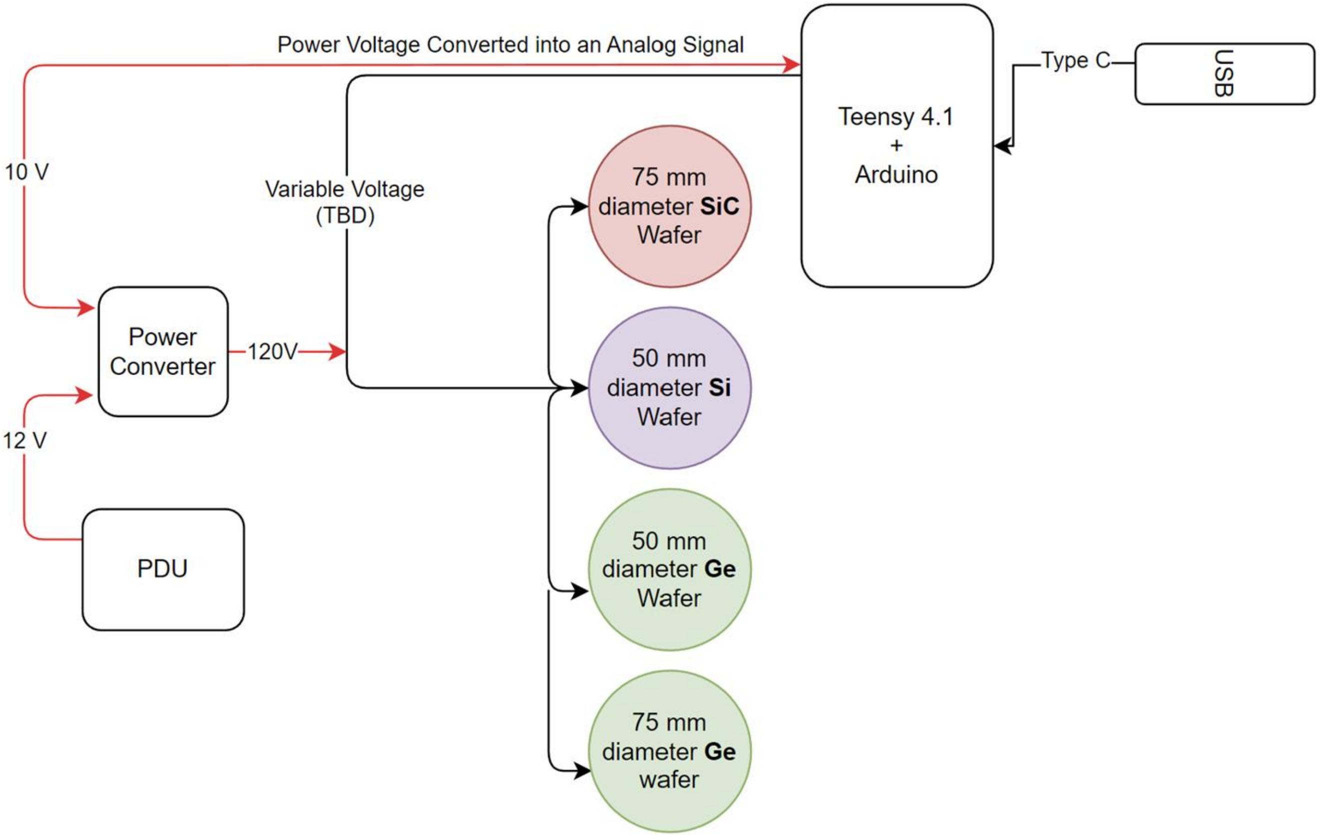
# Power Usage by Mode (Subsys. On/Off)

| Parts | | | *Power Usage by Mode (W)* | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subsystem** | **Component** | **Part Name/Datasheet** | **Initial Startup** | **Restart** | **Data Collect** | **Data Processing** | **Data Transmit** | **Data Received** | **Nascent** | **Active** | **Safe** | **Null** | **Thermal Emergency (Hot)** | **Thermal Emergency (Cold)** | **Battery Emergency** |
| | VIA | VIA | Off | Off | On | Off | Off | Off | Off | On | On | Off | Off | Off | Off |
| Payload | SEES | SEE | Off | Off | On | On | On | On | On | On | On | Off | Off | Off | Off |
| | Transmitter (TX) | ISISpace S Band Transmitter | Off | Off | On | Off | On | Off | Off | Off | Off | Off | Off | Off | Off |
| | Reciever (RX) | ISISpace UHF/VHF Transceiver | On | Off | On | Off | Off | On | On | On | On | Off | Off | Off | Off |
| COMMs | Deployment | UHF/VHF Antenna Deployer | On | Off | Off | Off | Off | Off | Off | Off | Off | Off | Off | Off | Off |
| | ISC | Teensy 4.1 | Off | Off | On | On | Off | Off | Off | On | On | Off | Off | Off | Off |
| | ISC | Raspberry Pi Zero | Off | Off | On | On | Off | Off | Off | On | On | Off | Off | Off | Off |
| OBC | OBC | ISIS OBC | On | Off | On | On | On | On | On | On | On | Off | Off | On | Off |
| | Gyroscope | | | | | | | | | | | | Off | Off | Off |
| | Magnetometer | | Off | Off | On | On | On | On | On | On | On | Off | Off | Off | Off |
| | Accelerometer | BMX160 | | | | | | | | | | | Off | Off | Off |
| | GPS | S1216F8-BD | Off | Off | On | On | On | On | On | On | On | Off | Off | Off | Off |
| ADCS | Reaction Wheel | Gen 1 | Off | Off | On | On | On | On | On | On | On | Off | Off | Off | Off |
| | Heater | KHLVA-0502/(*) | Off | Off | Off | Off | Off | Off | **Off** | **Off** | **Off** | Off | Off | On | Off |
| Thermal | Thermal Sensors x5 | TMP36F | Off | Off | On | On | On | On | On | On | On | Off | On | On | Off |
| | Battery Board | PyCubed | On | Off | On | On | On | On | On | On | On | Off | On | On | On |
| EPS | Distribution Unit | Artemis Design | On | Off | On | On | On | On | On | On | On | Off | On | On | On |

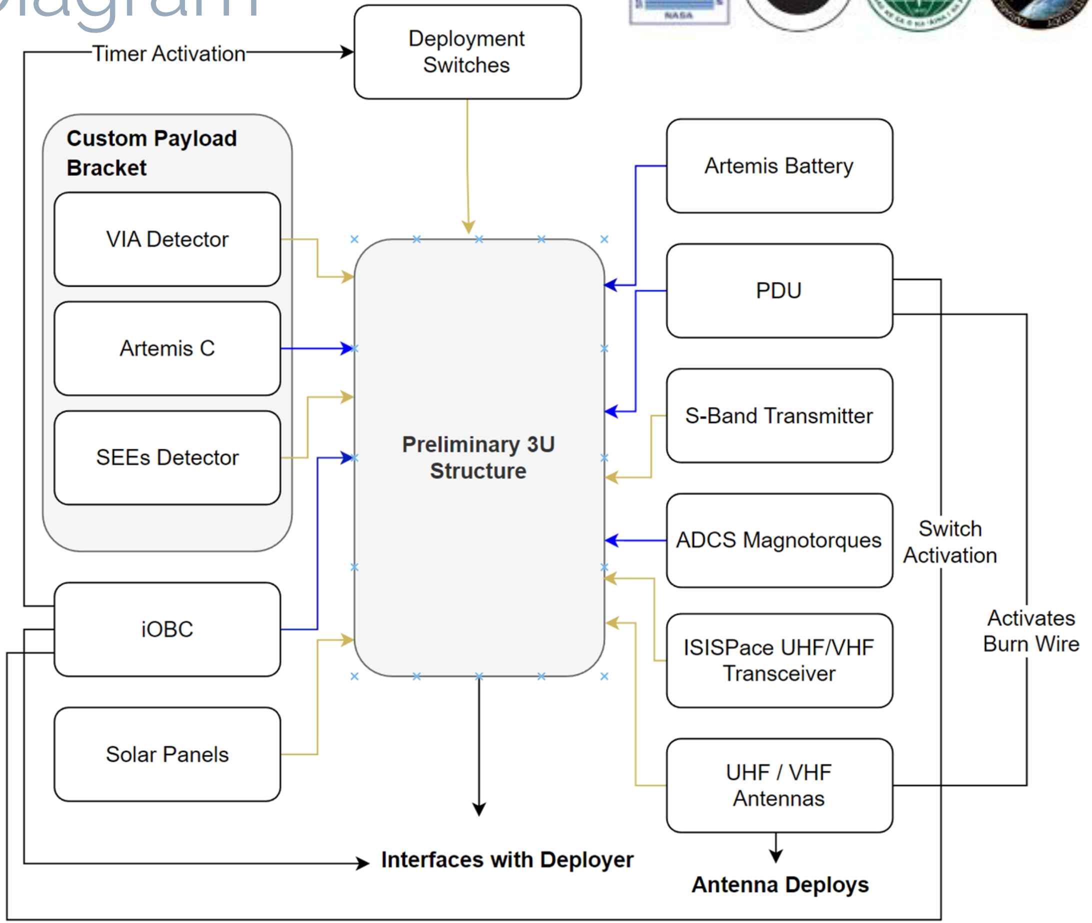
# Spacecraft System Diagram



# SEEs Detector Diagram



# Structures Diagram



# Thermal Diagram