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Active Thermal Control for the Multispectral Earth Sensors (ACMES) Mission

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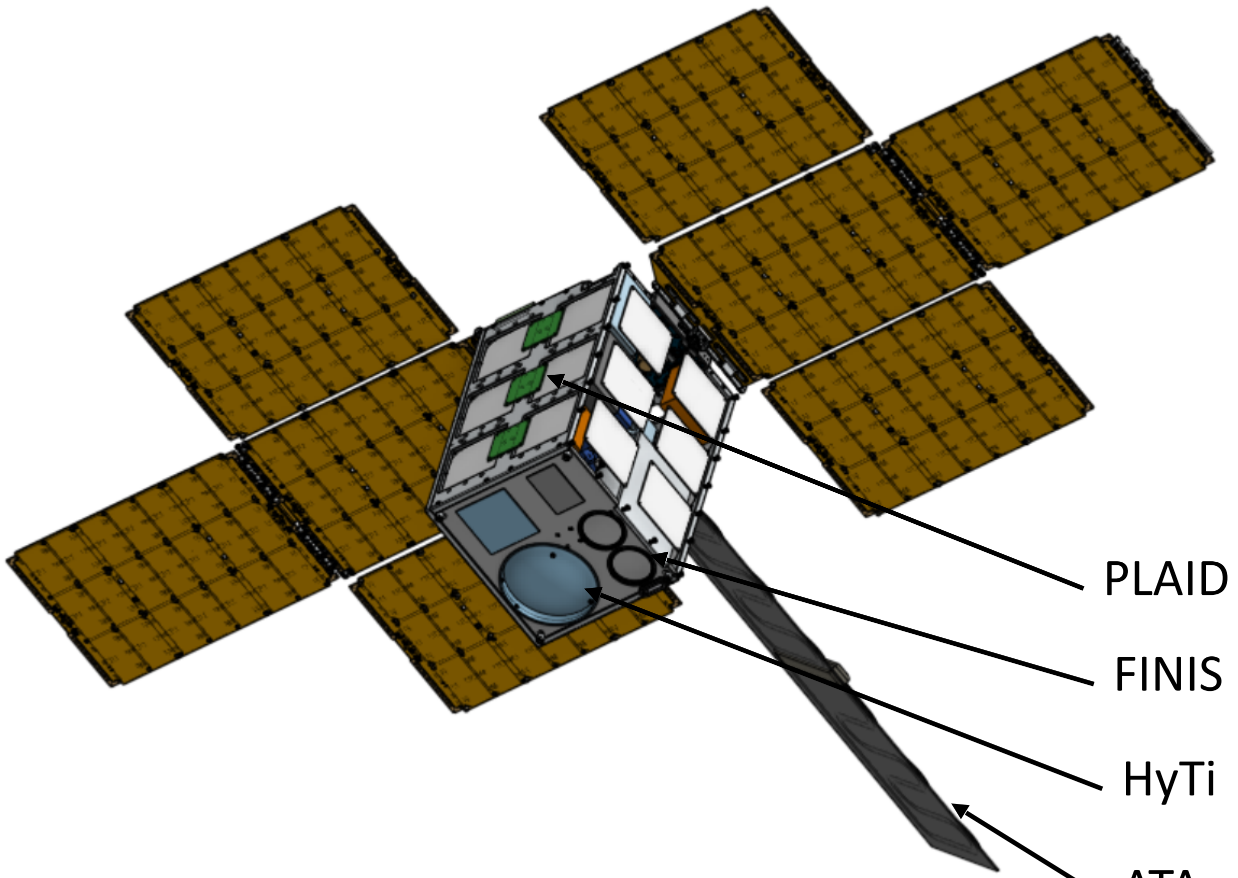
Presentation Outline

- ACMES
    - Overview
    - HyTi 2.0
    - Mission Concept
    - System Breakout
- Active Thermal Control
    - ATA
- Student Payloads
    - FINIS
    - PLAID



ACMES: 12U CubeSat

ACMES NASA InVEST Mission

Primary Goal 1.0: Enable the operation of cryogenic optical instruments on CubeSats.

Objective 1.1) Demonstrate on-orbit the active thermal control of the HyTi instrument

Objective 1.2) Demonstrate on-orbit the thermal control of the ACMES high-power CubeSat.

Secondary Goal 2.0: Provide LWIR observations of the Earth's surface.

Objective 2.1) Effectively operate a multispectral sensor as if it were part of a scientific mission to observe the land masses of the Earth for at least one year (up to four years).

Objective 2.2) Demonstrate the effectiveness of non-mechanical scanning multispectral sensor technology.

Tertiary Goal 3.0: Create unique opportunities for a diverse set of students to contribute to NASA's work in exploration and science.

Objective 3.1) Provide research and satellite development experiences that enable students to contribute to the ACMES mission through the FINIS and PLAID payloads.

Objective 3.2) Inspire students to contribute to NASA's work in exploration and science.

Hyperspectral Thermal Imager (HyTI) Version 2.0

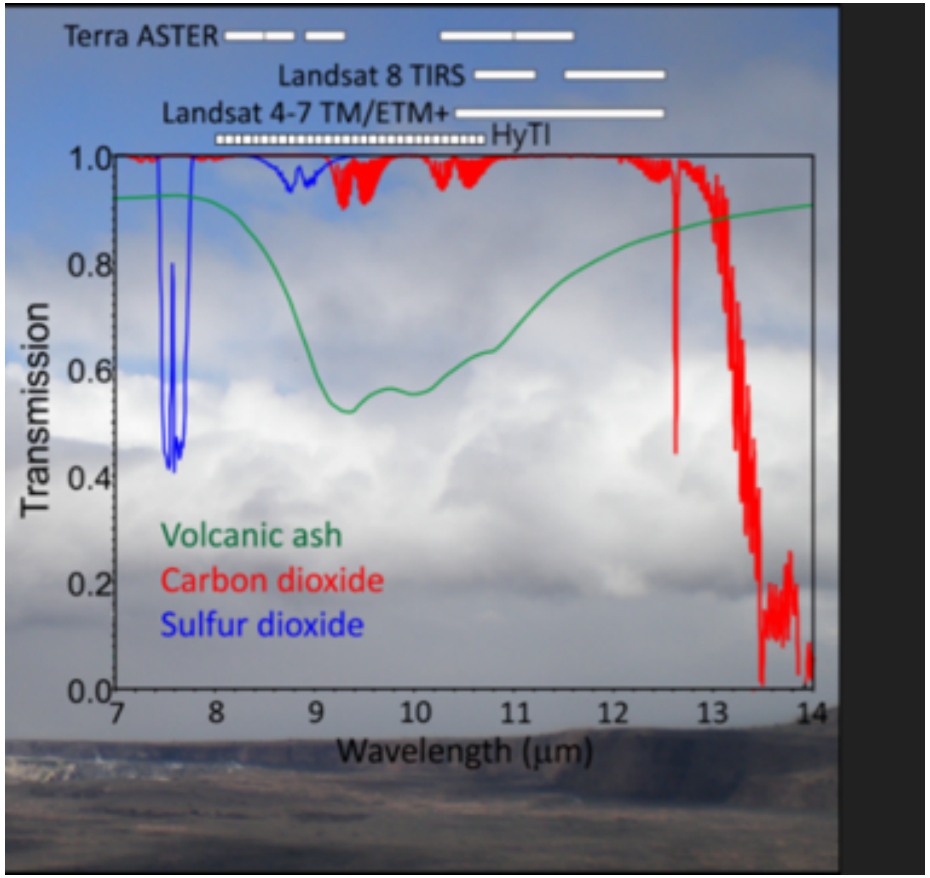
HyTi is an advanced high spatial, high spectral LWIR hyperspectral imager for LandSat-like observations of the Earth. The second generation of HyTi (HyTi 2.0) will fly with the ACMES mission as one of the two primary payloads

<u>HyTi 2.0</u>

- Second generation HyTi Instrument
- No moving parts spectrometer
- 100% Ground-Mapping
- High spatial (<45 m)
- LWIR (8-10.7 microns)
- High spectral (25 bands)
- Narrow band NE△Ts of < 0.3 K

Hawaii Space Flight Center

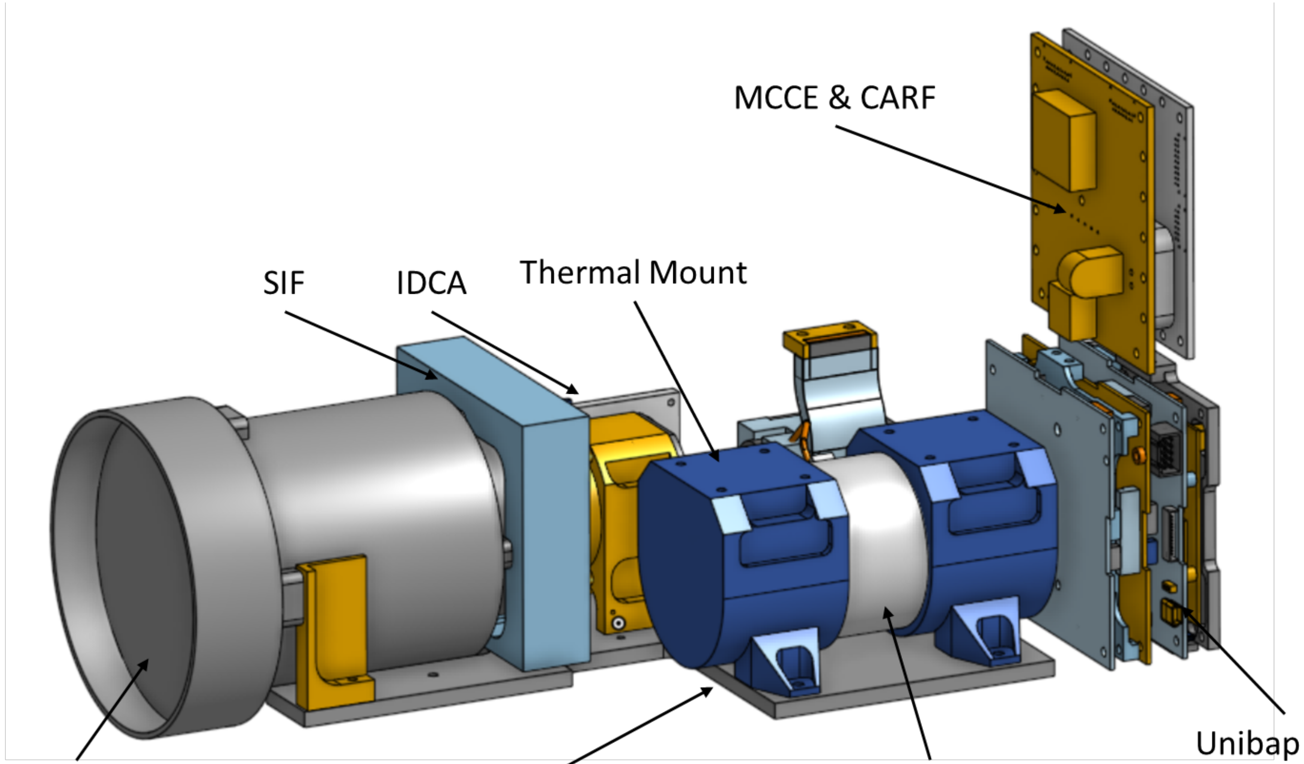
Funded by NASA ESTO InVEST



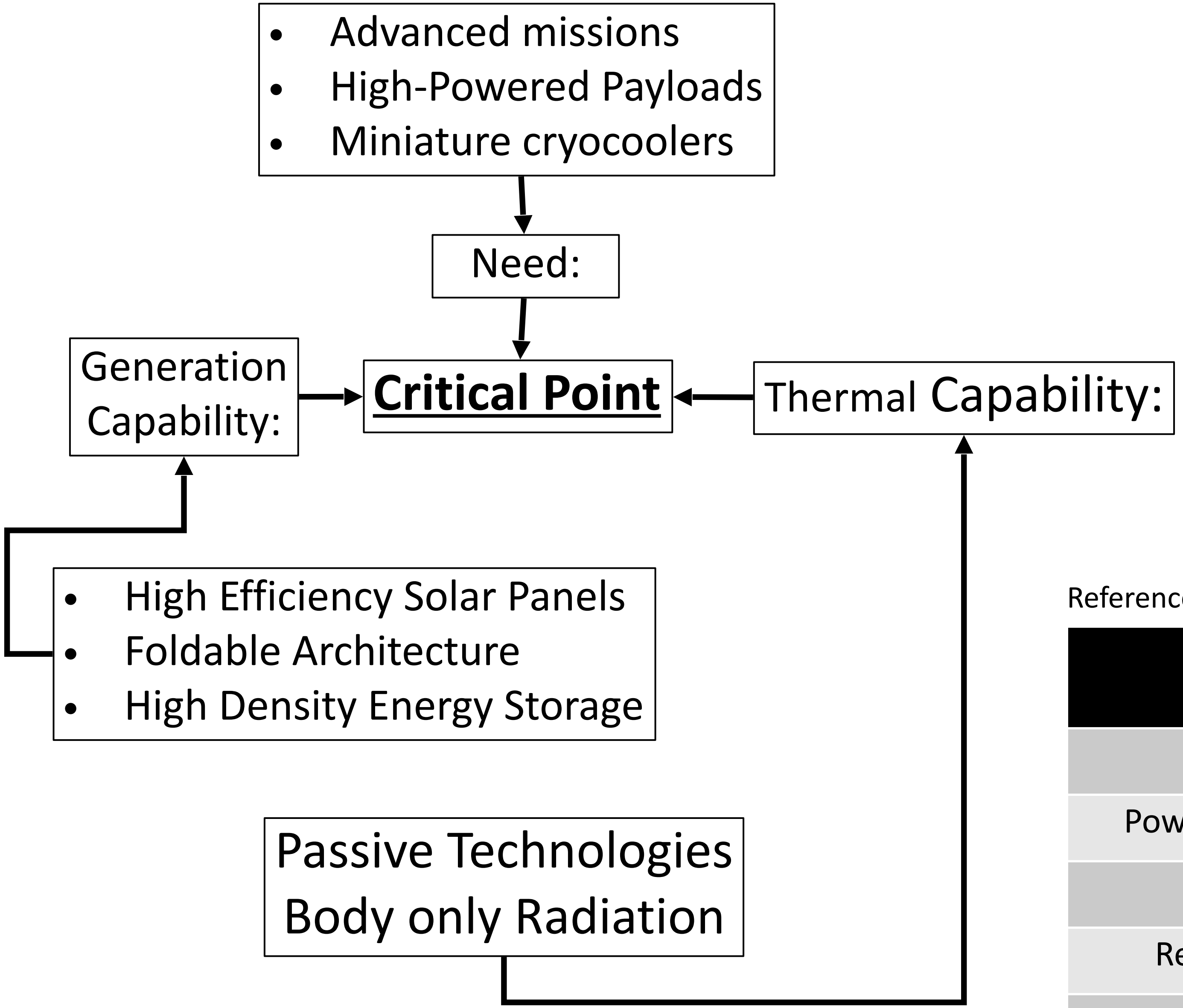
HyTi-2.0

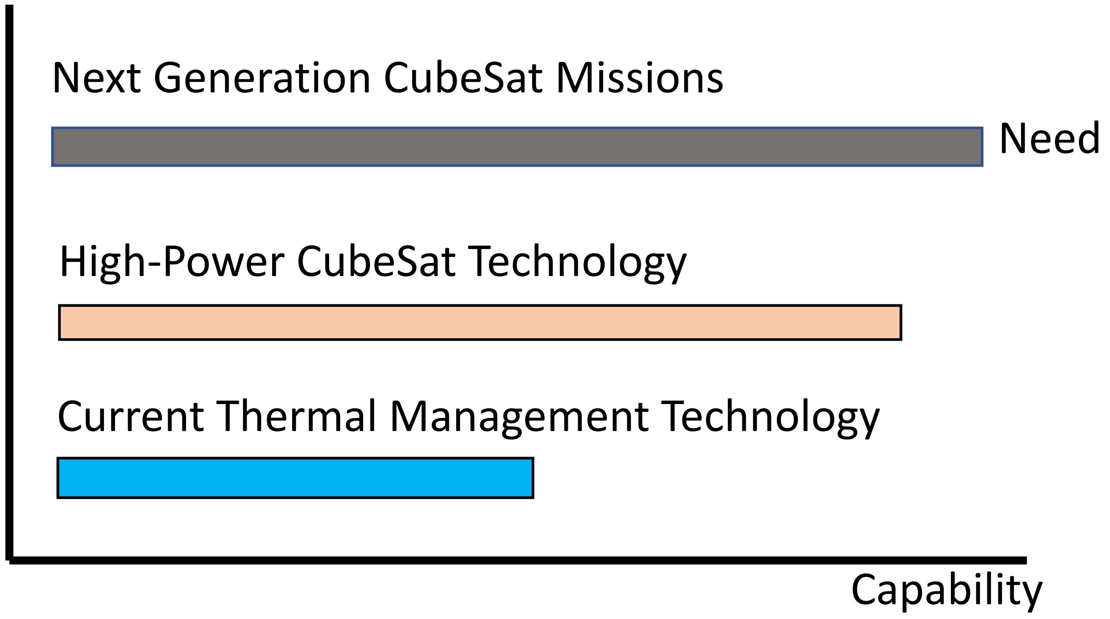
- Hot-Bird focal plane array---1280 x 1024
- >140 Hz sampling rate
- Subcooled to 68 K to 72 K
- UniBAP IX-10 high performance computer
    - Terabytes of data collection
    - Onboard data processing from L0 to L1
- AIM SF100 cryocooler
    - Integrated cryogenic Dewar

HyTi 2.0 Architecture



The Need for Active Thermal Control





Reference: CubeSat Handbook

Parameters	Geo Comm Sat.	12U
Dimensions [m]	3.0 X 3.0 6.0	0.2 X 0.2 X 0.3
Power [W] *Two Largest surfaces	5000	178 W
Radiator Area [m^2]	42.88	0.12
Rejected Heat Flux [W/m^2]	117	1483
Ratio	>13	

ACMES Mission Overview

Mission scope

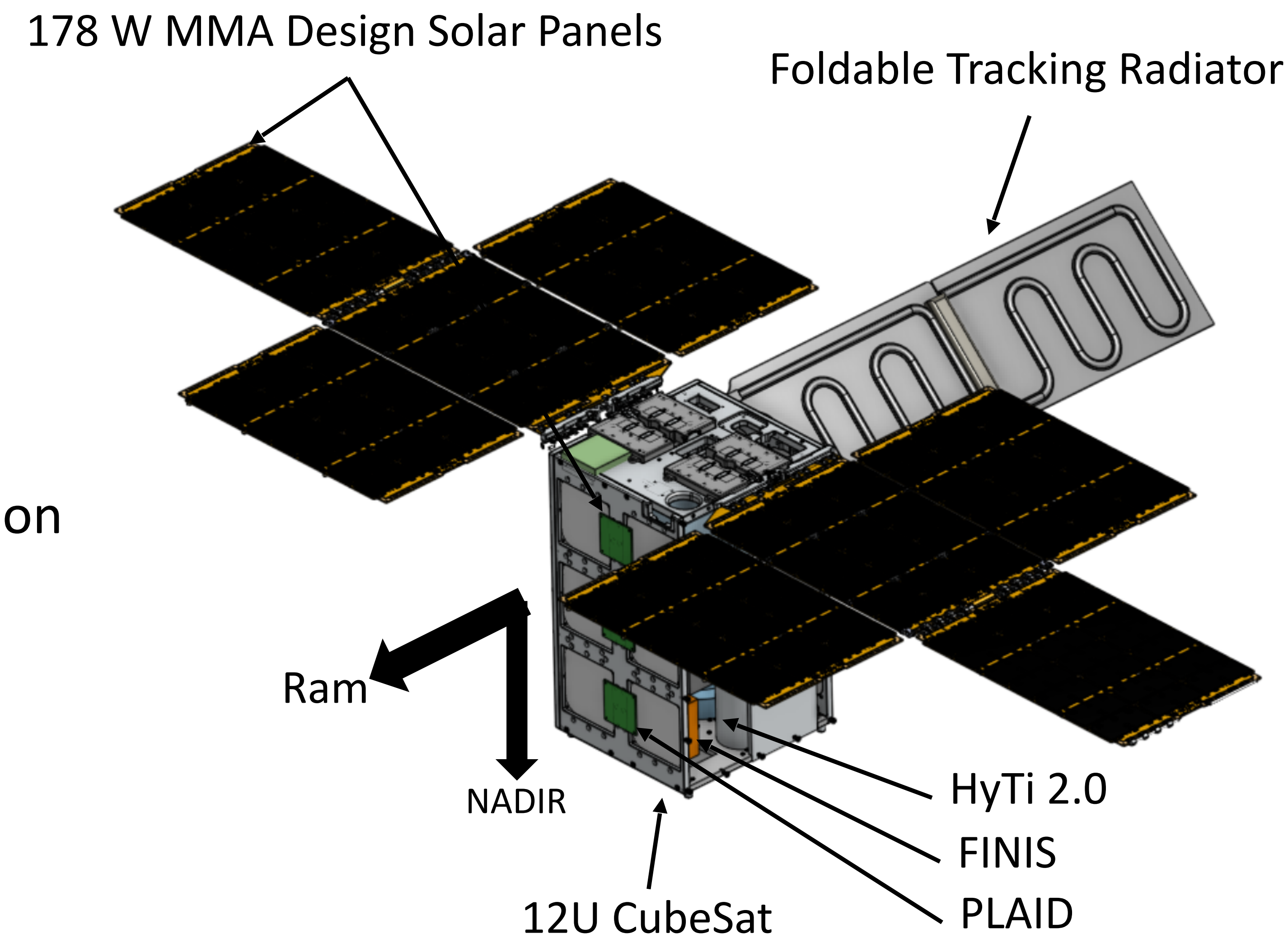
- CubeSat active thermal control
- LWIR observations of the earth
- Student learning opportunities

Lifetime

- One Year Technology demonstration
- Three Year Science mission

Orbit

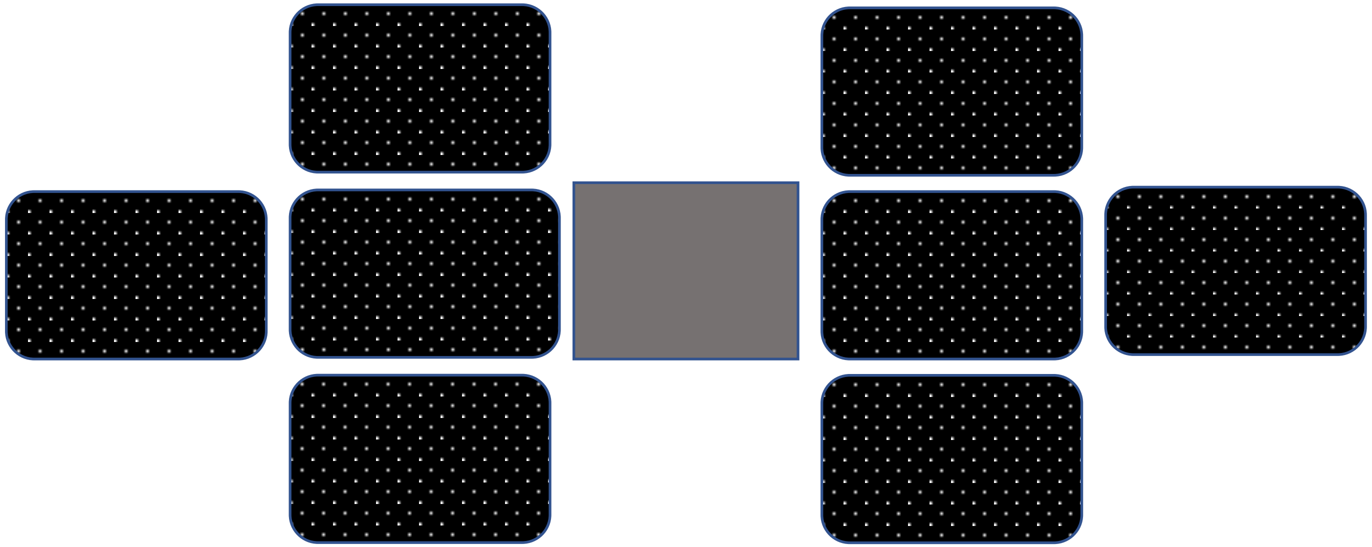
- 550 km orbit
- Noon-Midnight Sun Synchronous



ACMES Mission Overview

- 12U CubeSat Chassis
- +120 W Orbit Average Power
- Active thermal control
- Thermal Rejection
  - +80 W (over +100 W)
- +150 GB/Day Telemetry
- Onboard Propulsion
- Multiple Payloads
- Onboard Calibration

ACMES Solar Array Architecture



MMA Design Solar Arrays

Resource Allocations (ACMES Systems Level 2.0 Break Down)			
ACMES Element	Telemetry (GBytes/ Day)	Average Power (Watts)	12U Bus Mass (kg)
Maximum Possible Value	168	120	24

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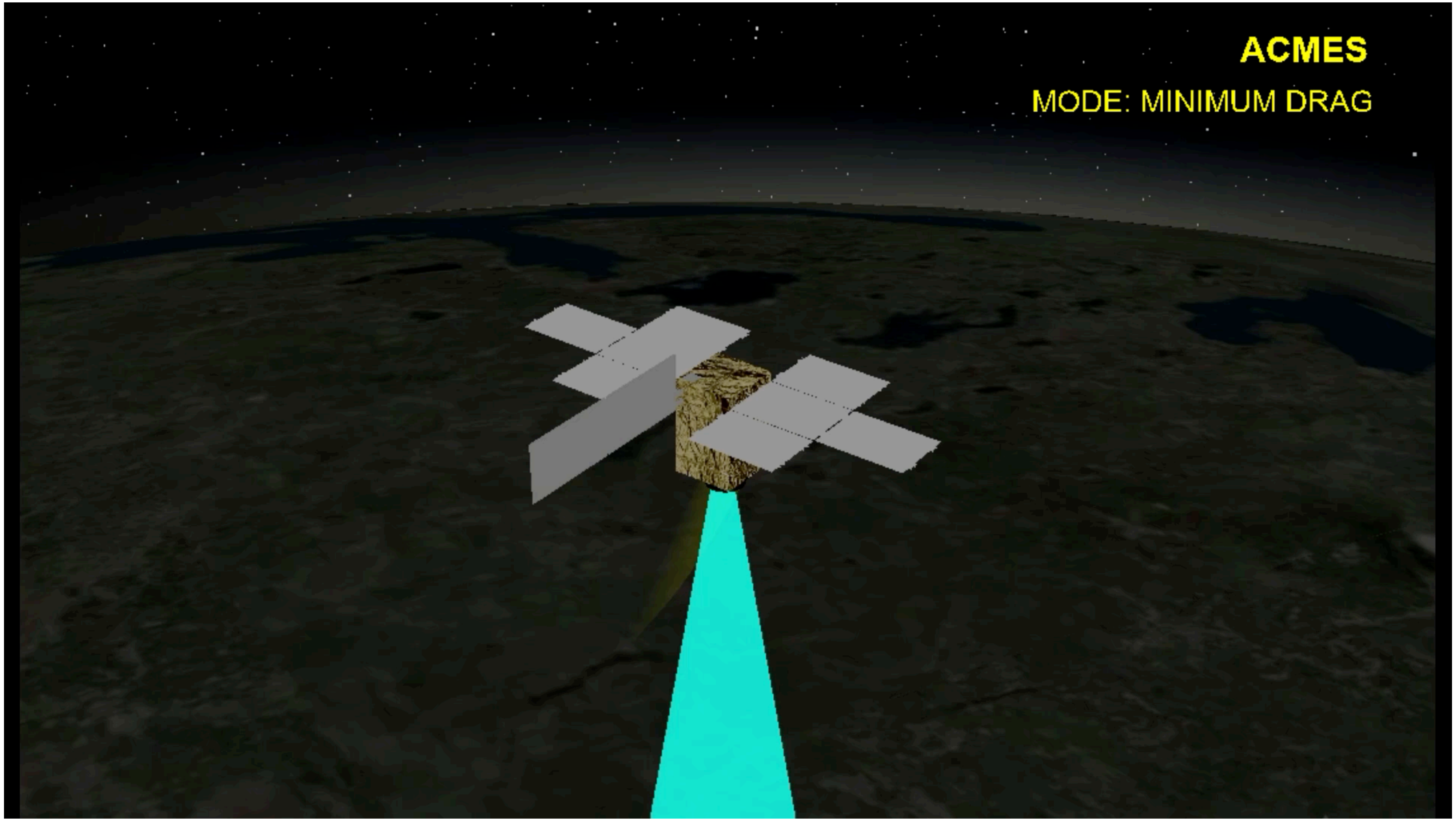
ACMES Operational Concept



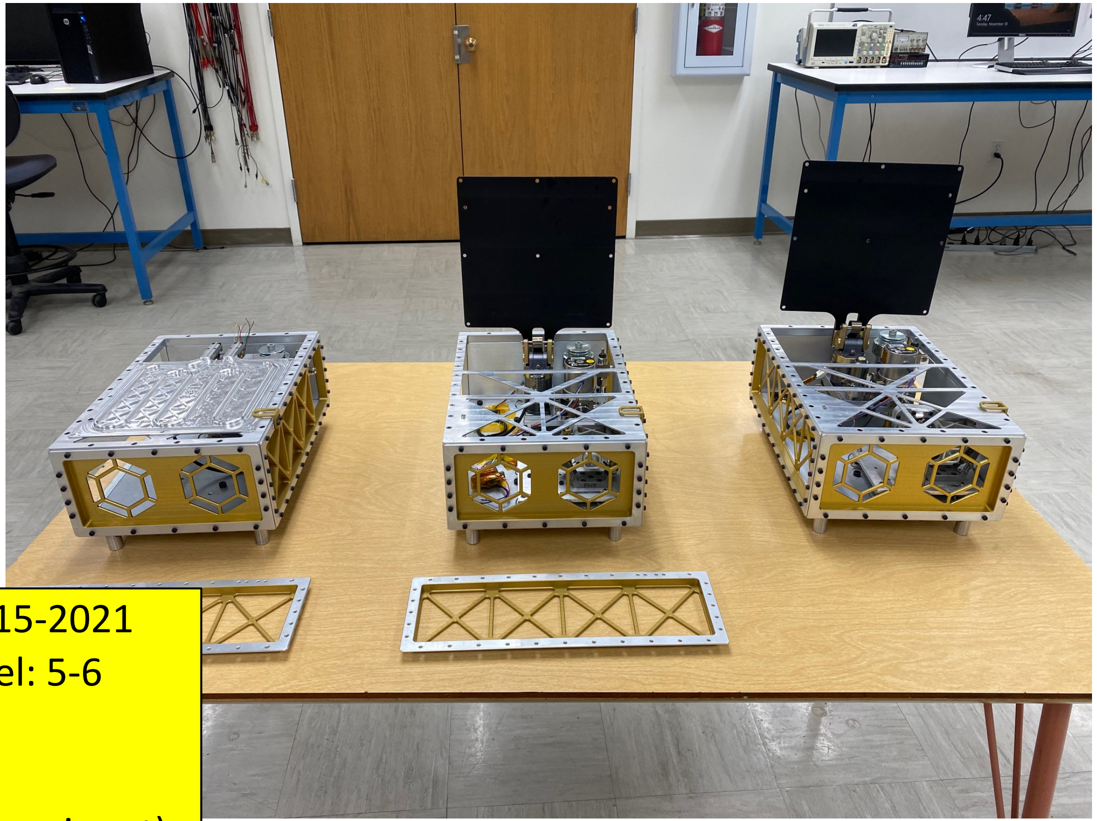
CubeSat Active Thermal Control

Future advanced CubeSat missions require higher power and accommodation of higher heat flux payloads. Therefore, as CubeSat power grows, CubeSat thermal control has to keep up.

- Bus thermal environment management
- Payload or system thermal control
- High power rejection
  - Scalable with solar array growth
- 3D UAM fabrication Multi-functional design

Applications:

- LEO Electro-Optical Instrumentation
- High powered payload support
- Cryocooler Integration and Support
- Heliophysics & Earth Science
- Lunar & Deep Space Missions
- Heat transfer across articulating joints



ATA Ground Prototype

Period of Performance 2015-2021
Technology Readiness Level: 5-6

Mass / Power / Volume
<~1.5 kg (3 lbs), < 3 W (pump input), < 1 U (~0.5U)

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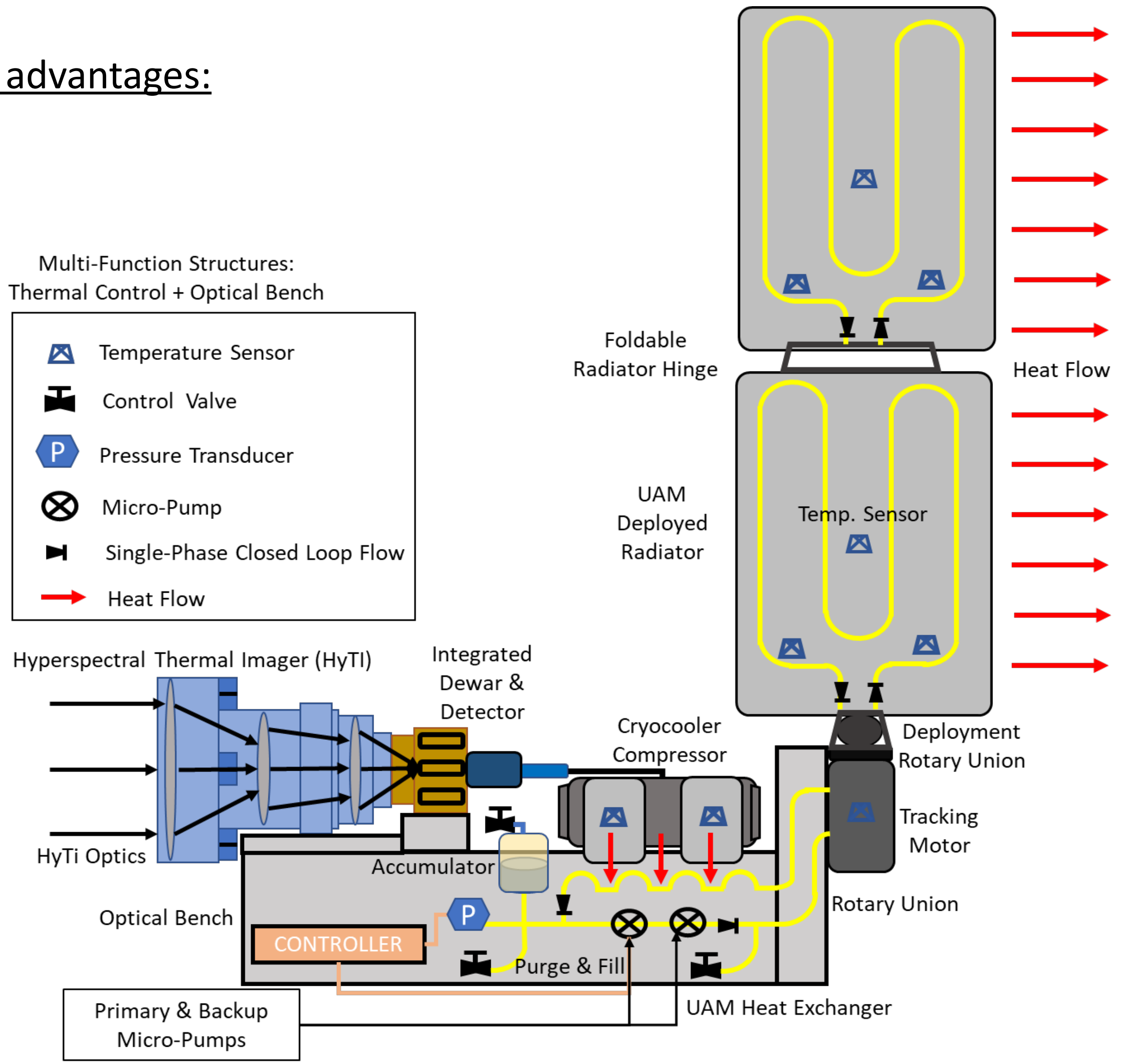
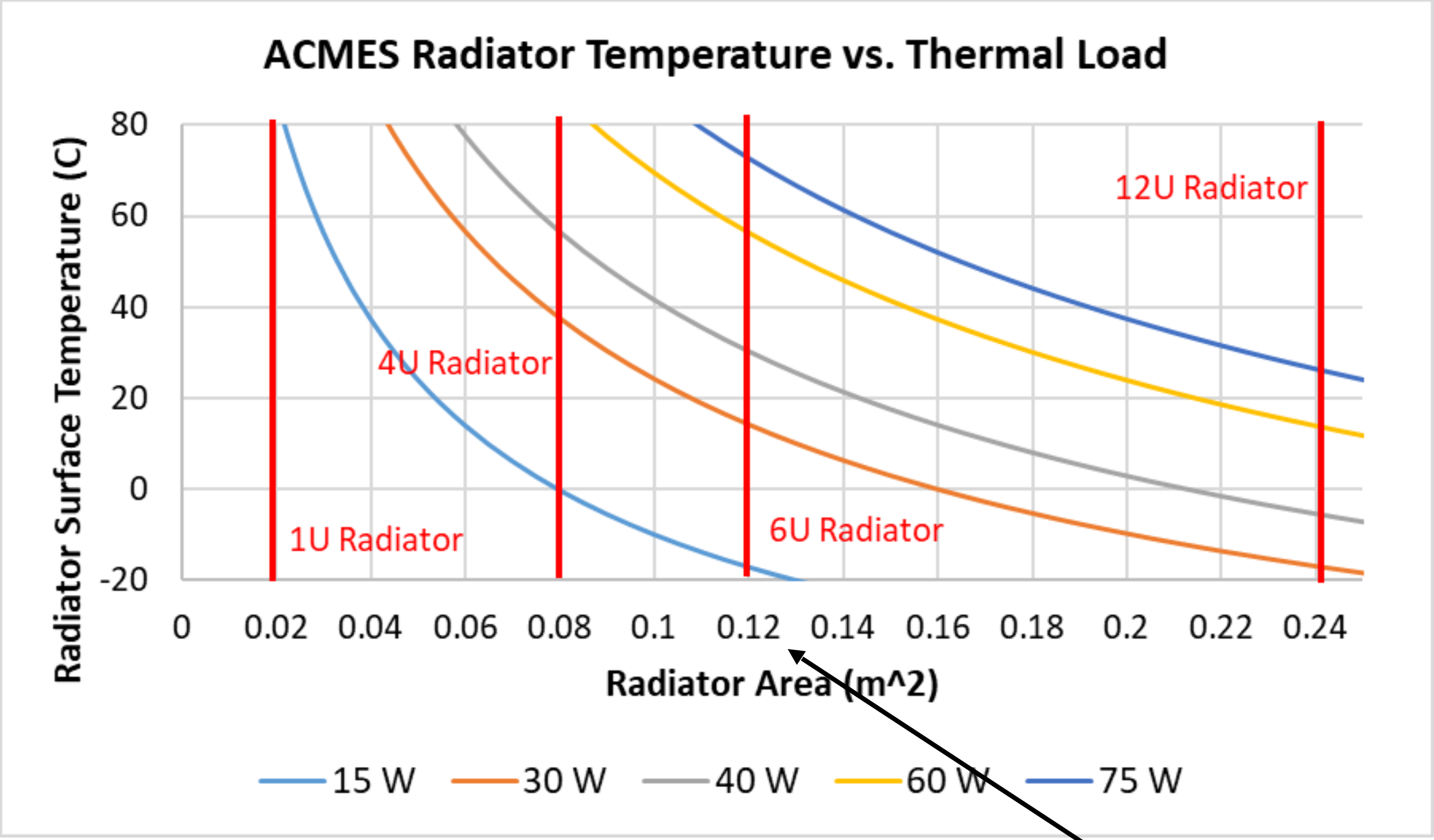
The ATA is a single-phase Mechanically Pumped Fluid Loop (MPFL) heat exchanger.

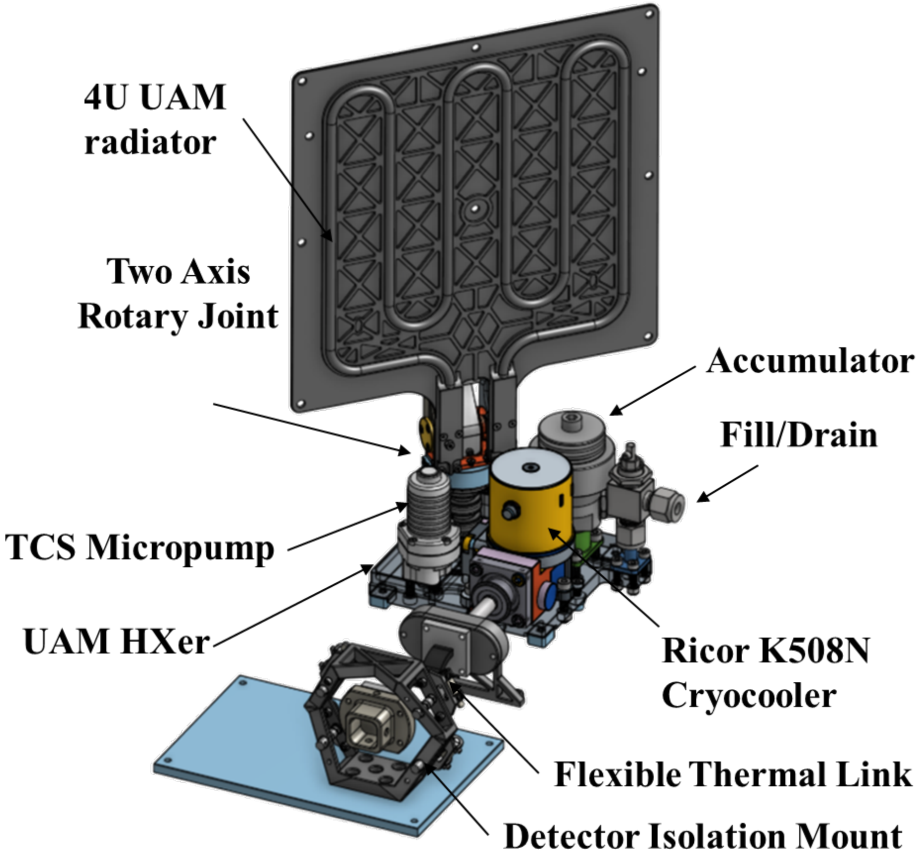
Pumped fluid loop thermal control systems provide the following advantages:

- Scalability– deployable radiator
  - Radiator can scale with solar arrays
- Enables thermal bus architecture
- Efficient (near isothermal) radiator performance
- High heat flux acquisition
  - reduced interface temperatures (near isothermal)
- Bulk fluid heat transfer
  - High thermal conductance & capacitance from source to sink
  - Near zero temperature drop across articulating fluid joints
- Enables positive feedback and control of the system temperature possible with variations in flow rate
- Radiator tracking allows for more optimal heat rejection
- Improved payload reliability (optimal thermal accommodation)
  - Greater system temperature stability
  - Reduced payload interface temperatures



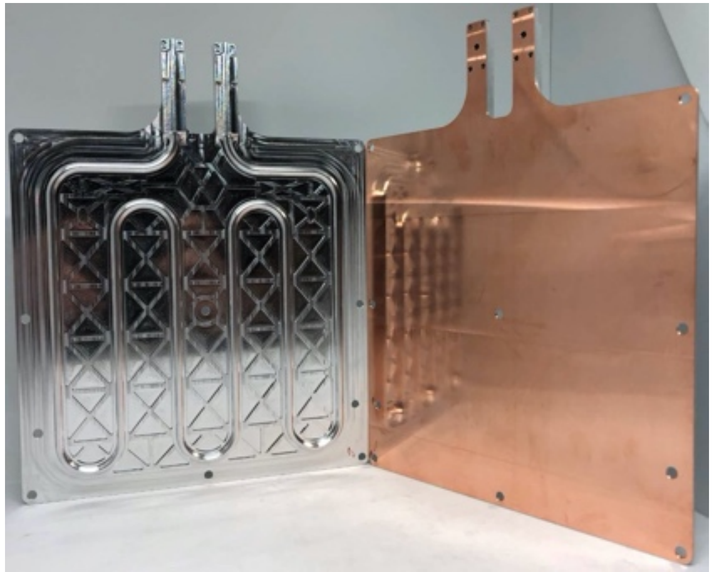
ATA



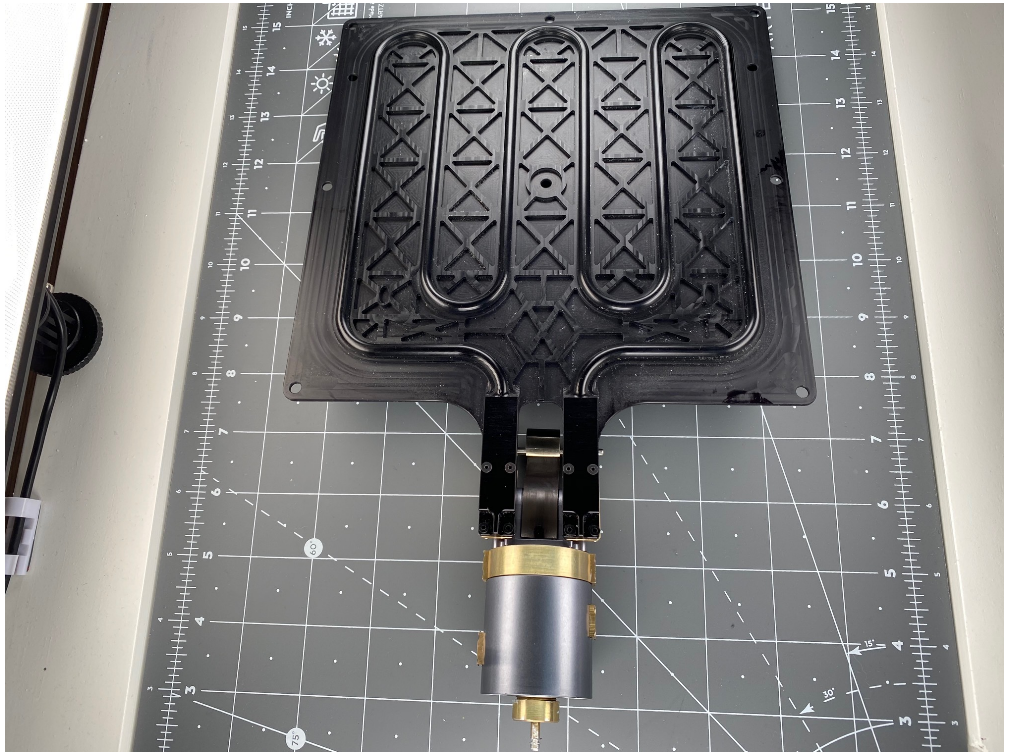


1U ATA Prototype
(1U excludes detector mount)

>Requires a Foldable Radiator



ATA UAM Radiator



ATA UAM 4U Radiator and Rotary Union

ATA Rotary Union and 90° Deploy

ATA Rotary Union Elements

ATA Micro-Pumps

ATA Piston Accumulators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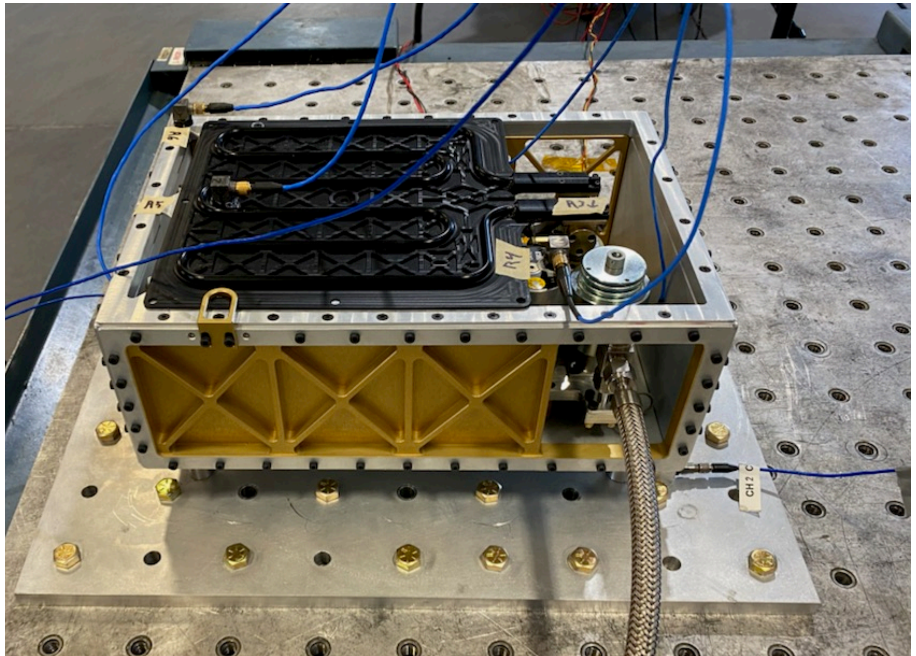
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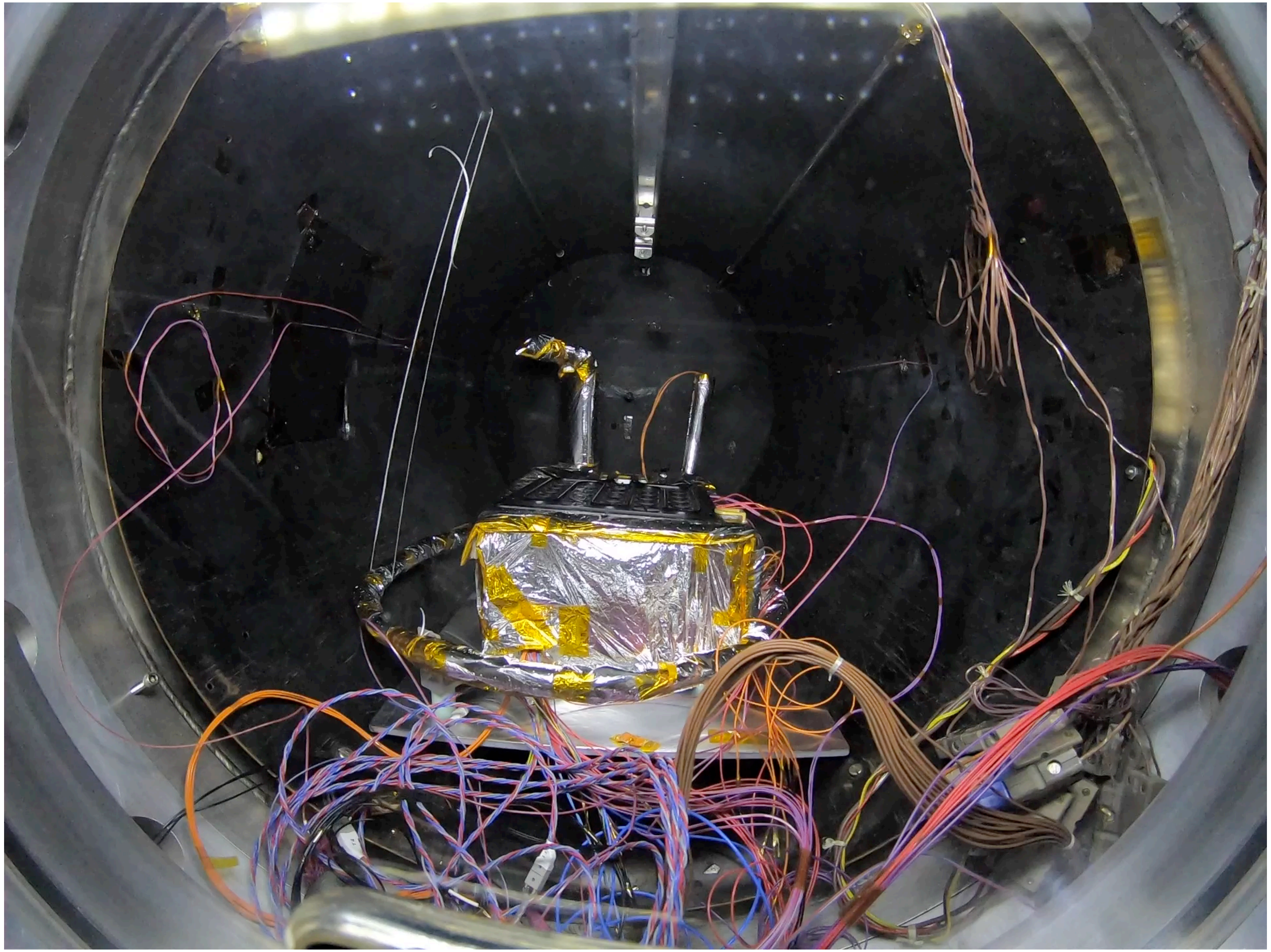
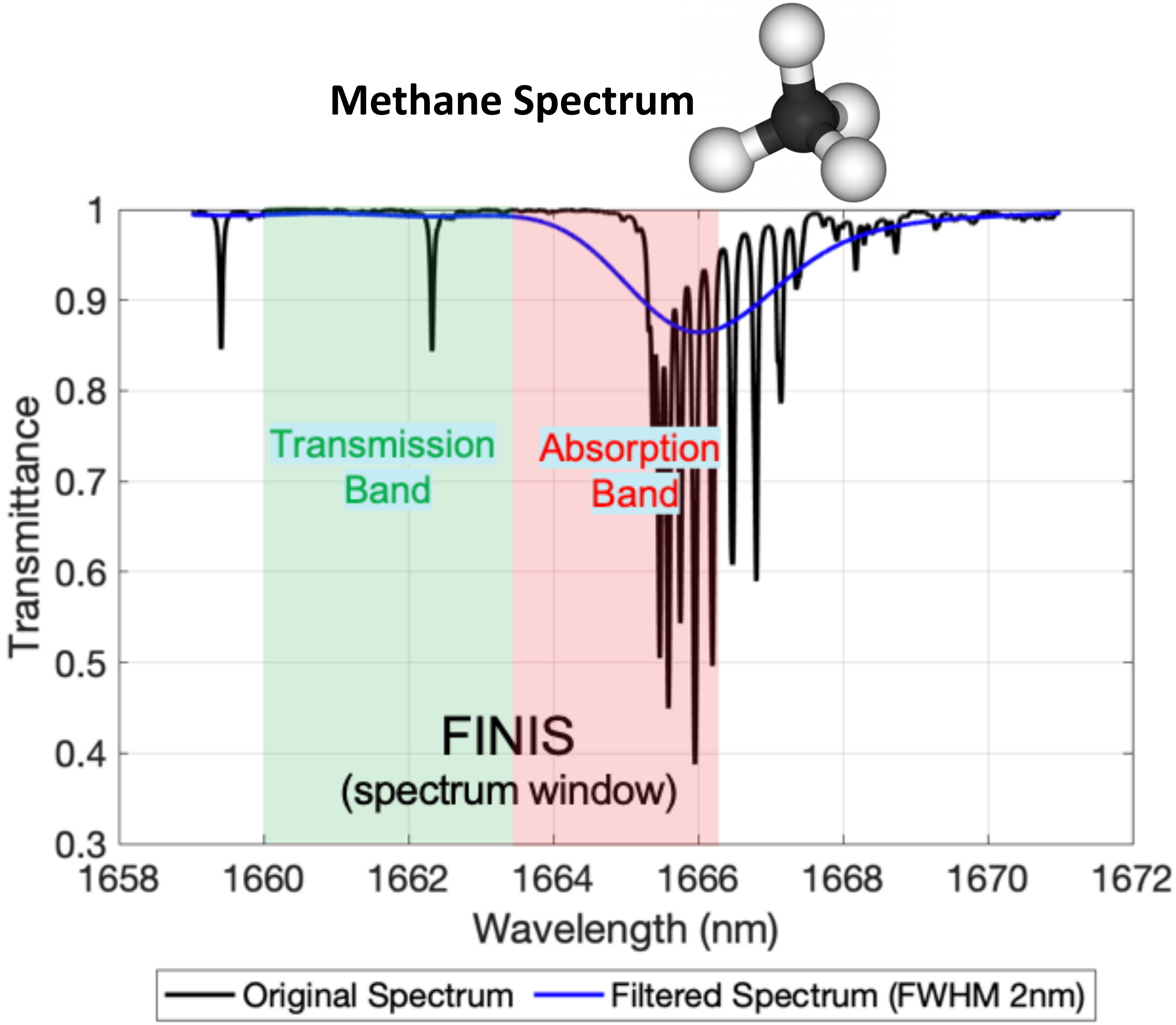
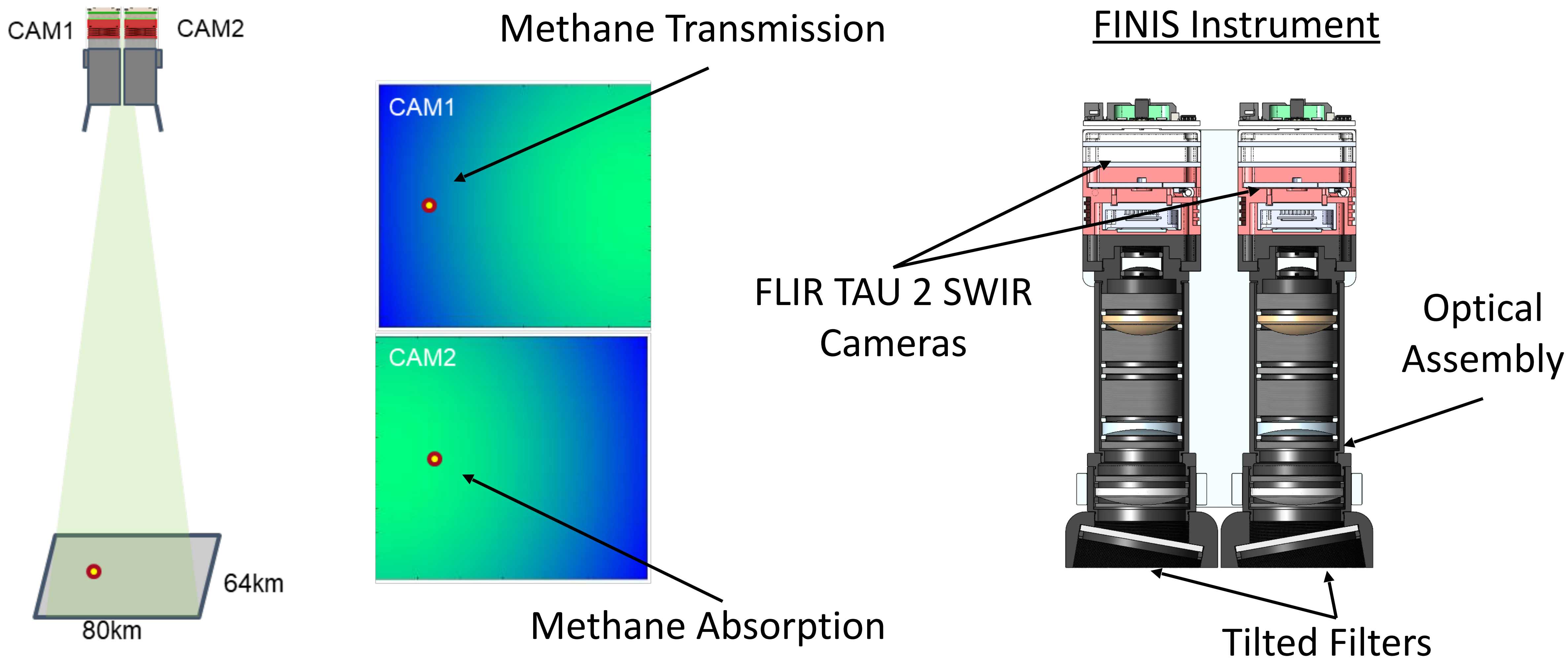


Filter Incident Narrow-band Infrared Spectrometer (FINIS)

- Daytime atmospheric Methane detection
- Low power & compact instrument
- Tilted filter narrow band spectrometer
- Absorption near 1.666 μm
- Ideal for CubeSat's and Small Satellites



FINIS



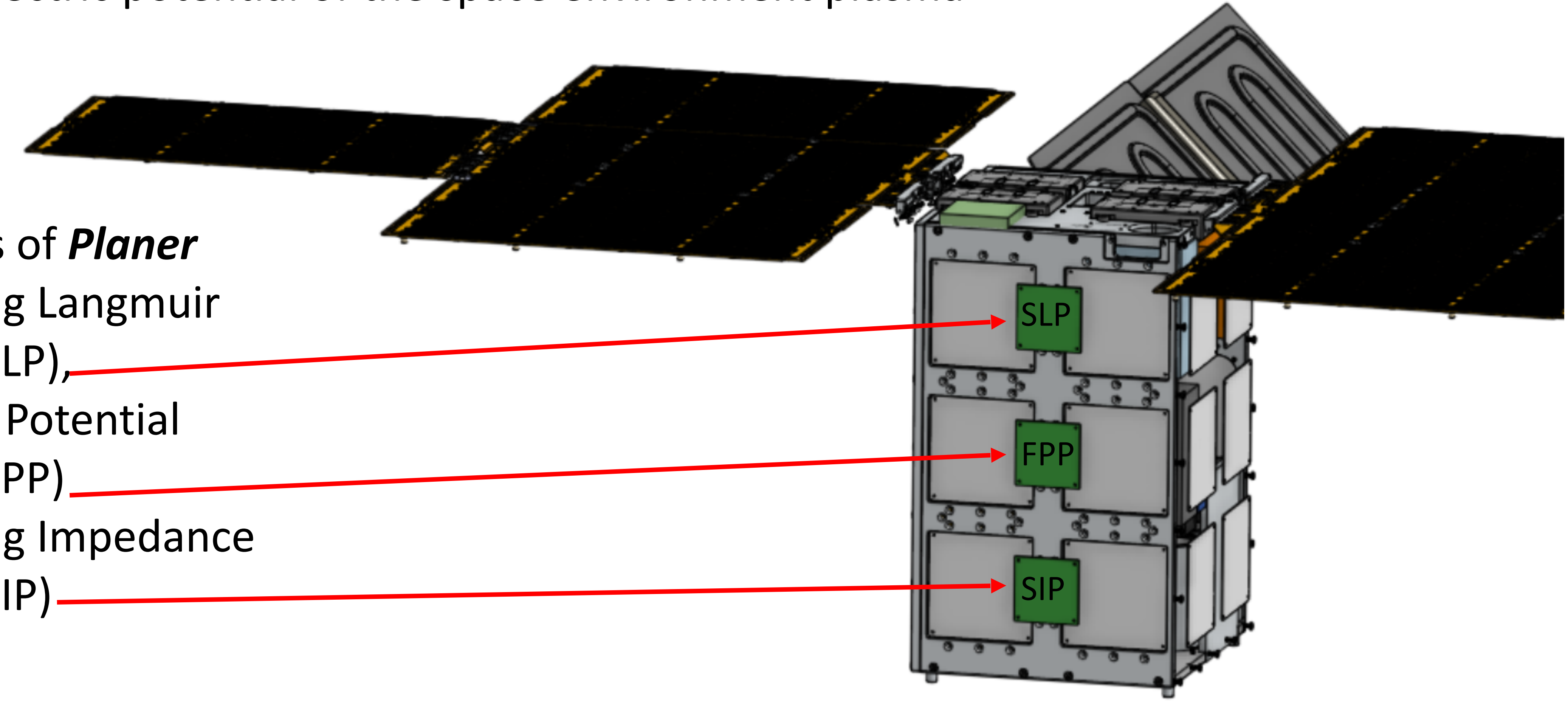
CAM1
CAM2
64km
80km
Methane Transmission
CAM1
CAM2
Methane Absorption
FINIS Instrument
FLIR TAU 2 SWIR Cameras
Optical Assembly
Tilted Filters

PLAD (RF Impedance Probe)

A novel planar style RF-impedance probe for measurement of electron temperature, density, and electric potential of the space environment plasma

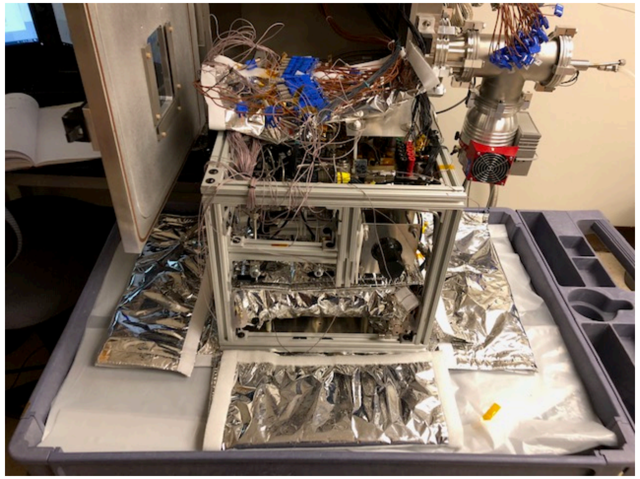
PLAID Consists of ***Planer***

- Sweeping Langmuir Probe (SLP),
- Floating Potential Probe (FPP)
- Sweeping Impedance Probe (SIP)



Previous work, Funding and Support

- Active CryoCubeSat
  - Technology proof of concept
  - NASA Small Satellite Technology Development Grant
  - Supported by Jet Propulsion Laboratory
- Active Thermal Architecture
  - Flight prototype---ground based qualification and testing
  - NASA Small Satellite Technology Development Grant
  - Supported by Jet Propulsion Laboratory



ACCS TVAC Characterization Test Cube

- Active Cooling for Multi-Spectral Earth Sensors funded by the NASA Earth Science Technology Office In Space Validation of Earth Science Technologies
  - NASA ESTO
  - Utah State University
  - Hawaii Space Flight Laboratory
  - Orion Space Solutions