



# **CubeSat Proximity Operations Demonstration (CPOD) Vehicle Avionics and Design**

**August CubeSat Workshop 2015**

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VP, Space Vehicles**

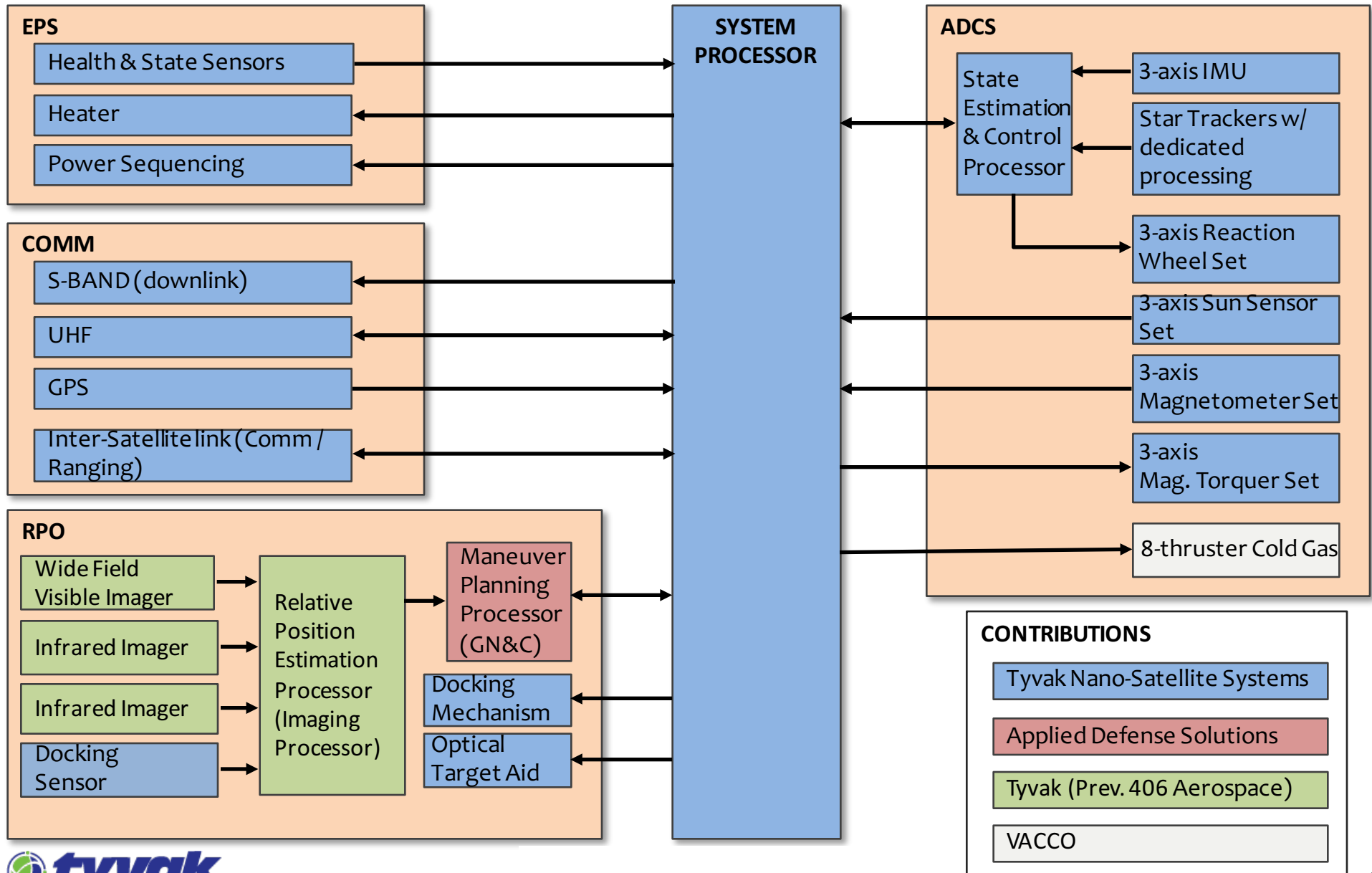
# CPOD: Big Capability in a Small Package

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<b>Communications</b>	Directional Simplex S-band to Ground (2.2Ghz)
	Directional Half-Duplex Inter-Satellite Link (ISL) (2.4Ghz)
	Omni-Directional Half-Duplex UHF (400Mhz)
<b>ADCS</b>	3-Axis Multi-Objective Pointing with Momentum Dumping
	Contingency Coarse Pointing Mode
	Ground Tracking, Inertial Pointing, LVLH, Sun
<b>Navigation</b>	GPS L1 for Position and Velocity
	Relative Bearing and Distance Determination (Optical, RF)
	Relative Attitude Determination (Optical)
	On-Board Navigation Solutions and Delta-V for Manuevers
<b>EPS</b>	Sufficient Peak Power, and Energy Storage
	Distributed Power Interfaces to Subsystems
	Docking Mechanism (Electro-Magnet)
<b>Mechanical</b>	Deployables (UHF Antenna, Solar Panels, Vehicle Separation)
<b>C&amp;DH</b>	Vehicle Monitoring and Control
	Fault Management
	Inter-Processor Communication

# Space Vehicle Architecture

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# CPOD Configuration

4x Radios

5x Linux Computers

4x Deployables

6x Antennas

3x Microcontrollers

6x Imagers

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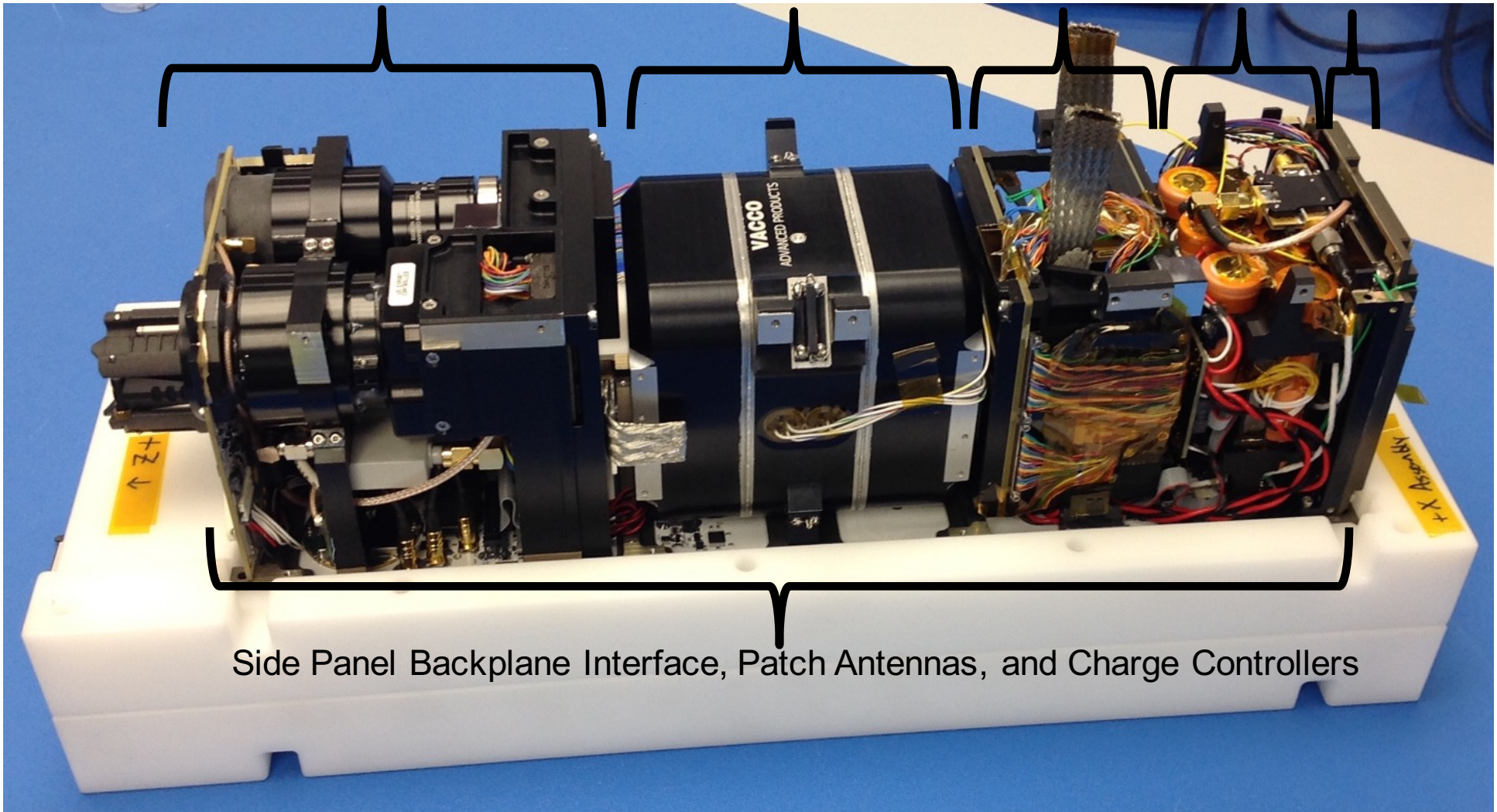
Navigation Solutions,  
GPS, Docking Mechanism

Cold Gas Propulsion

C&DH,  
ADCS

EPS

UHF  
S-Band

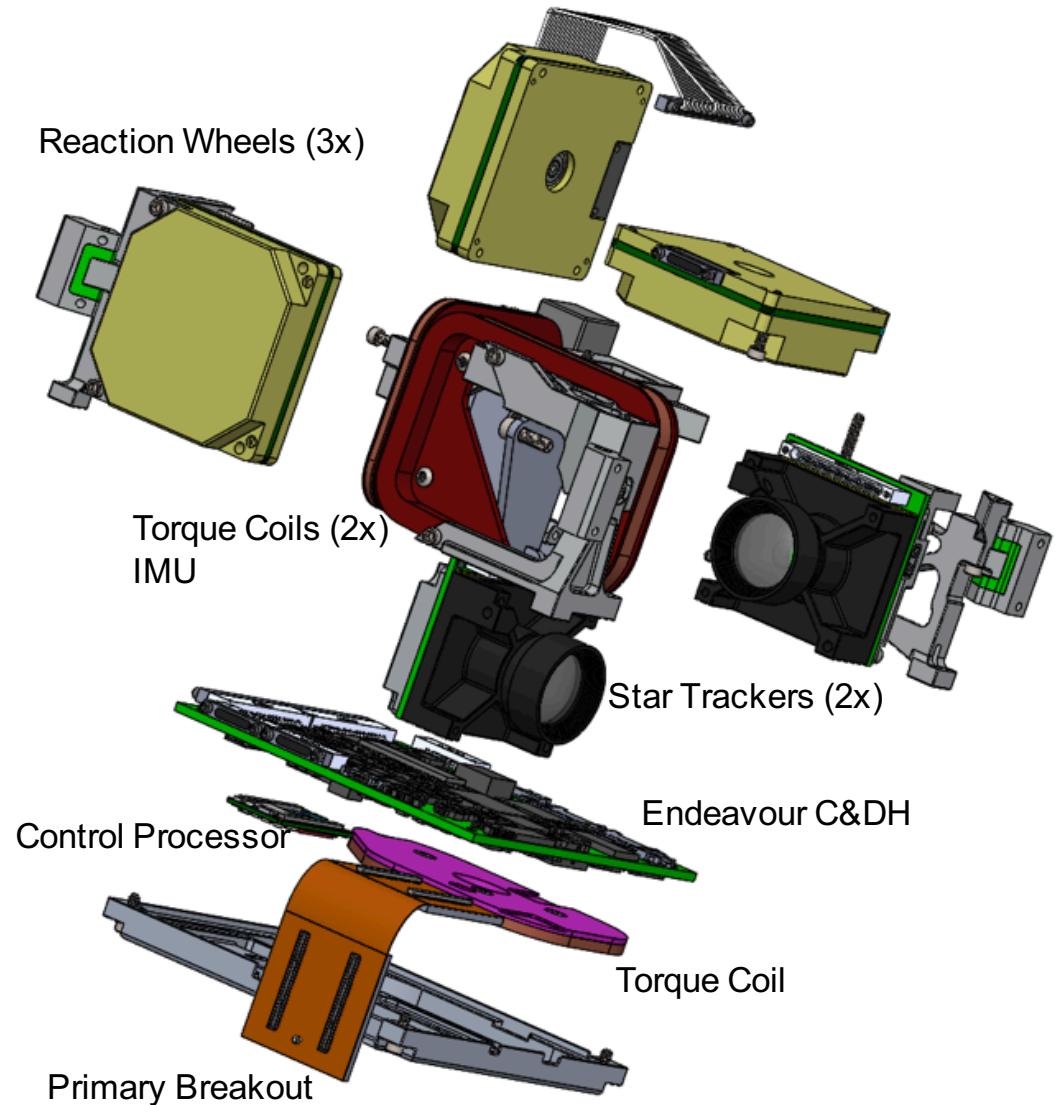
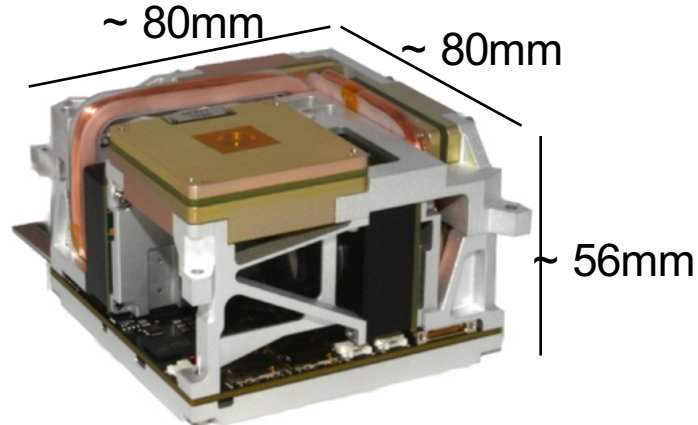


Side Panel Backplane Interface, Patch Antennas, and Charge Controllers

# Endeavor Vehicle: C&DH and ADCS 1/2U Solution

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- **C&DH Linux Processor**
  - Arm9 @ 400Mhz
- **ADCS Linux Processor**
  - Arm Cortex-A8 @ 800Mhz
- **Reaction Wheels (x3)**
  - 10mn-m-s; 3mN-m; 10000 RPM Max
- **Star Trackers (x2) and IMU**
  - Pitch/Yaw/Roll 10/10/80'' 1 $\sigma$
- **Magnetorquers (x3)**
  - 0.1 A-m<sup>2</sup> in all axis



# EPS – Battery Module and Solar Panels

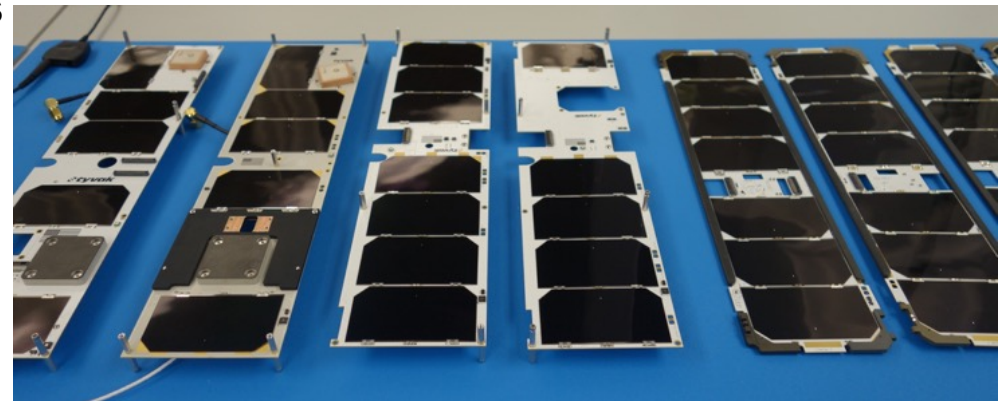
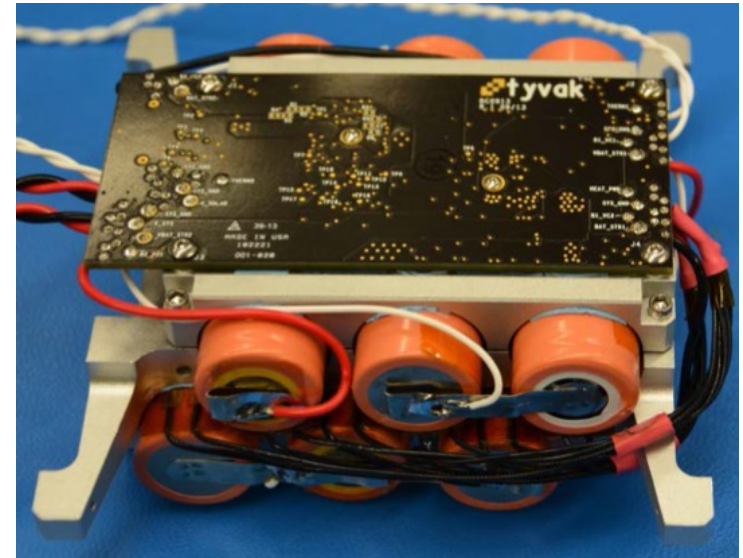
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- **Battery Module Features**

- 11.1V Unregulated System
- Greater than 80 watt power output capability
- Greater than 40 watt power input (charge) capability
- Temperature & power sensor telemetry
- Fail-safe battery heater controller
- Dual deployment switch power output inhibit

- **Solar Panels**

- Supports 3 to 5 cell strings
- Maximum Peak Power Tracking on Panels
- Deployable Configurations Available
- Thermal radiators
- Panels customized for the mission



# RF Communications

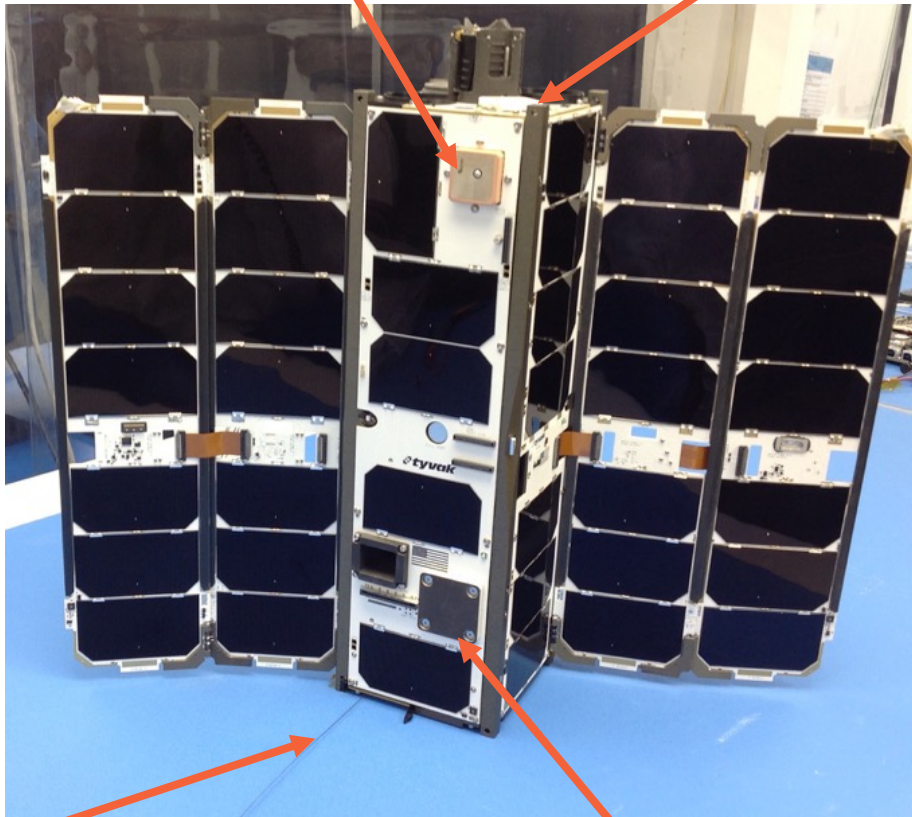
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## GPS Patch Antenna

L1 Band, Two Phased Elements

## Inter-Satellite Link

250kbps, RF Ranging @ 2.4Ghz

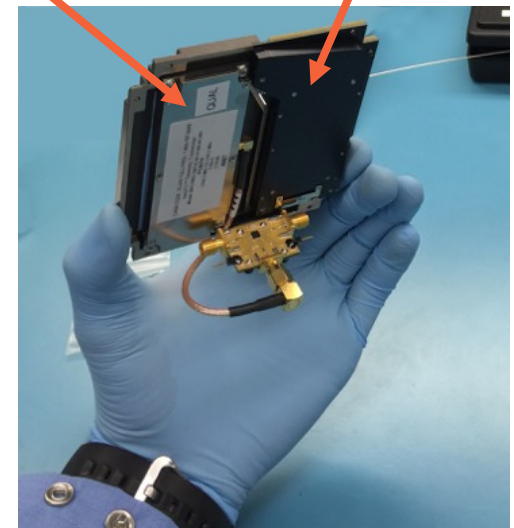


## UHF Half-Duplex Radio

9.6kbps GMSK @ 400Mhz

## S-Band Transmitter

1Mbps BPSK @ 2.2Ghz



## Deployable UHF Antenna

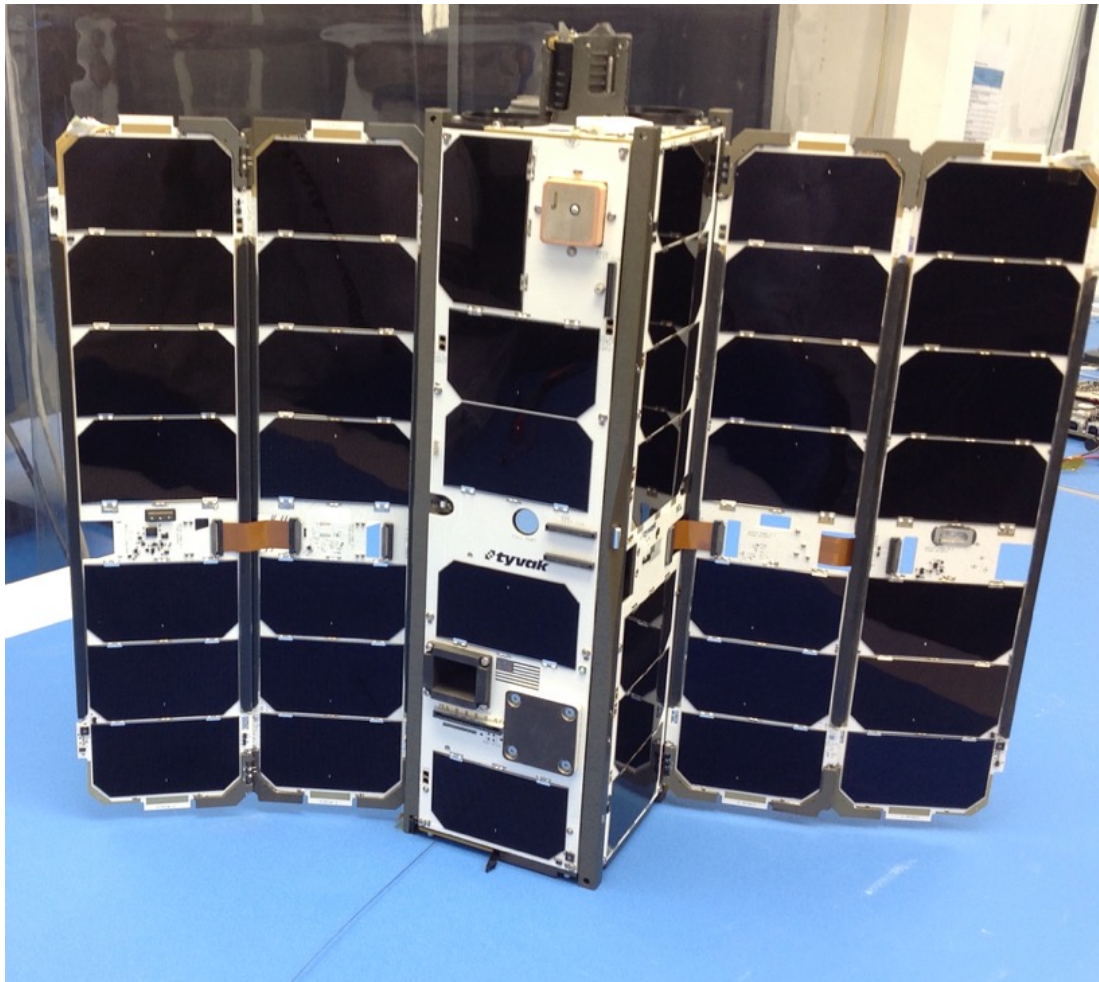
Omni-directional

## S-Band Patch Antenna

Two Switched Elements

# CPOD Performance Summary

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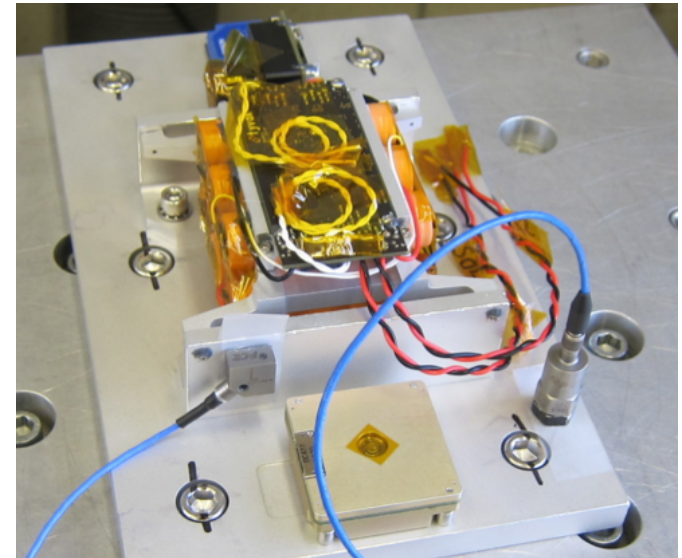
Capability	Specification	Comments
<b>Average Power Generated</b>	~17W to 30W OAP	Polar Sun-Sync
<b>Average Load</b>	~15W	Fully Active
<b>Pointing Accuracy</b>	<0.15 degrees	Star Trackers available under all mission scenarios
<b>Mission Data Downlink</b>	~60MB / day	UHF and S-Band
<b>Delta-V</b>	~30 m/s	Cold Gas
<b>Total Mass</b>	5.990kg	Wet Mass (13% Margin)



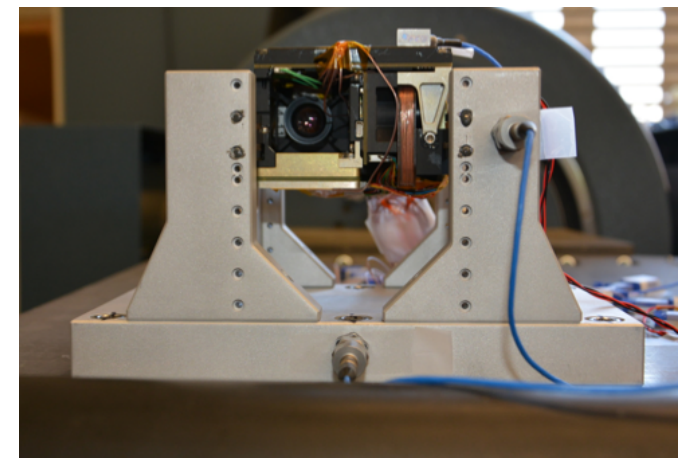
# Component and Subsystem Environmental Testing

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- **Early component and subsystem environmental testing used to reduce risk of issues at system level**
  - Risk reduction environmental testing completed on low TRL components (RWA, battery module, star camera, and IMU show on right)
  - Modules used to enable testing complex sub-systems before full vehicle integration (IRM, RPOD, etc.)
- **Lessons Learned**
  - Thermal test before thermal vacuum testing
  - Design for repeated assembly and disassembly of complex modules
  - Feature rich test interfaces are invaluable when attempting to understand issues without deintegration
  - Testing with non flight like surface finishes may hide surface roughness issues



Component Vibration Testing

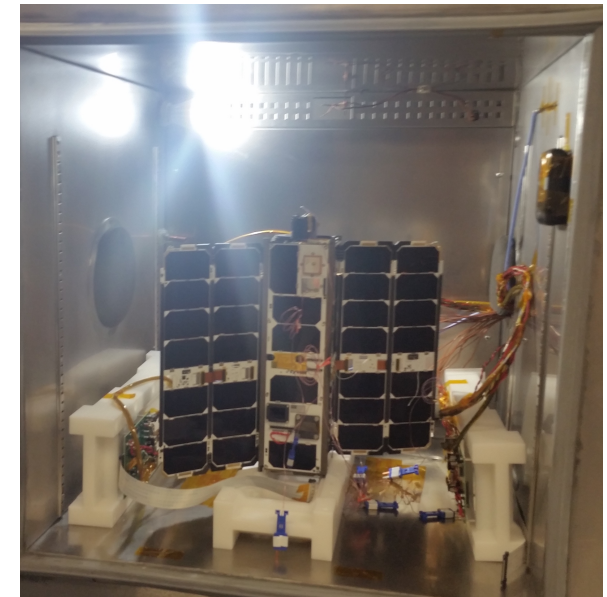


Subsystem Vibration Testing

# Vehicle Level Avionics Testing

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Test	Description	Status
Self RF Compatibility	Verify all radios operate to specification under all vehicle operational scenarios	Passed
Anechoic Chamber Testing	Perform anechoic chamber test of S-Band, ISL, and UHF Antennas	Passed
GPS Lock	Check that vehicle achieves GPS lock under all operating modes	Passed
Hardware In The Loop	Guidance, Navigation and Control simulations driving flight-like actuators	Passed
Night Sky Testing	Outdoor Night sky testing of IRM	Passed
Payload Calibration and Sensor Alignments	2 Visible, and 2 IR Imagers aligned with star-trackers and IMU.	Passed
Vibration	22 grms vibration test	Passed
Thermal Vacuum	Complete vehicle operations over thermal vacuum cycles	Passed



Vehicle Environmental

## Questions?

