MicroMAS: Updates on the Global Environmental Monitoring Nanosatellite Mission

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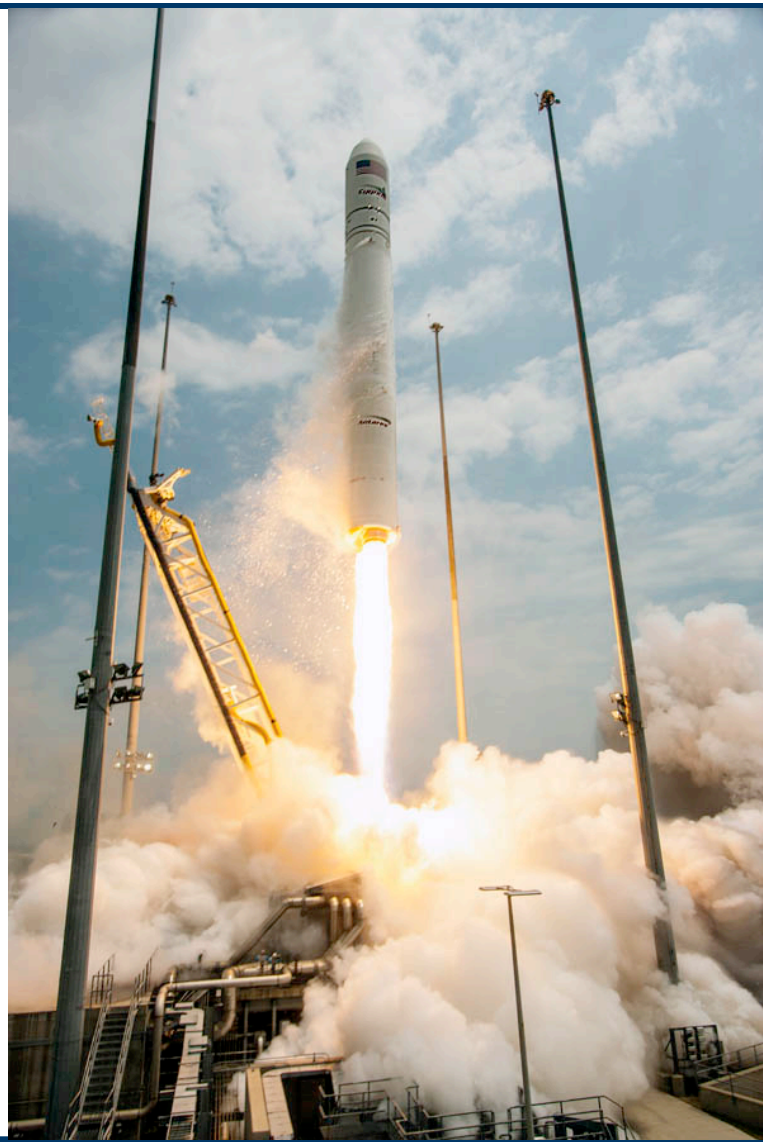
Outline

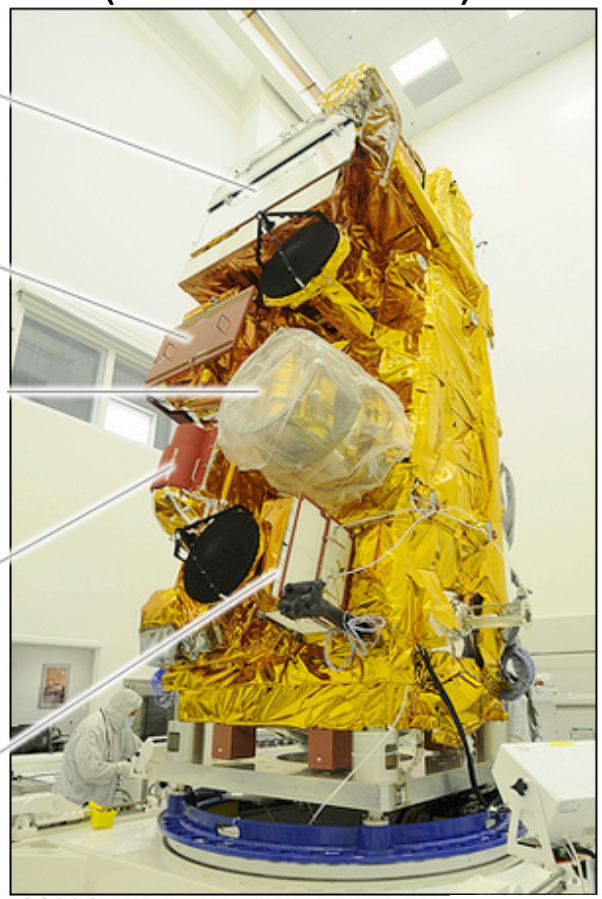
- Introduction and Motivation
- Radiometer Payload
- Spacecraft Bus Overview
- Prelaunch Test and Validation
- Summary

MicroMAS Launched July 13, 2014 (Orbital/Cygnus ISS Resupply)



Traditional Approach: Big Satellites

Suomi NPP Satellite (Launched Oct 2011)



2100 kg NASA/GSFC

NPP: National Polar Partnership

Current Approaches Unsustainable

- Expensive
- Long development cycles
- Very high failure impact

Independent Assessment

dependent ssessment

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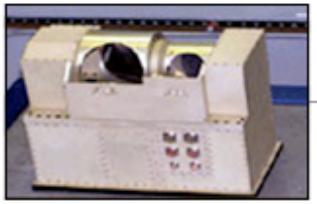
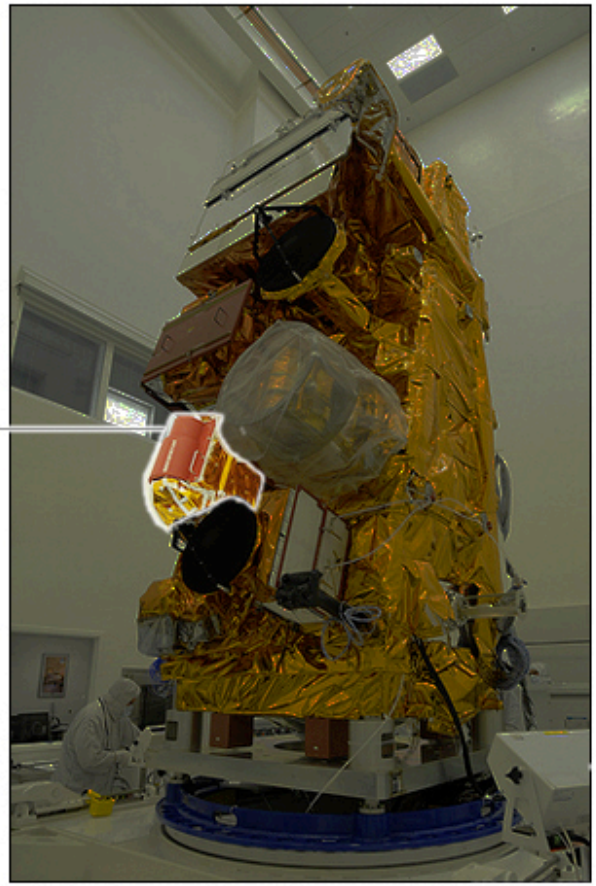
Focus: Microwave Sounding

Suomi NPP Satellite
(Launched Oct 2011)

Advanced Technology
Microwave Sounder
(ATMS)



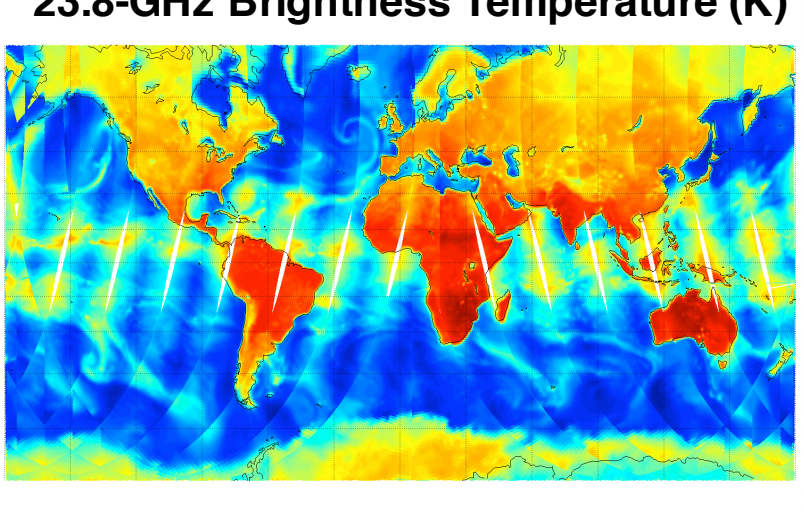
100 kg, 100 W



2100 kg NASA/GSFC

NPP: National Polar Partnership

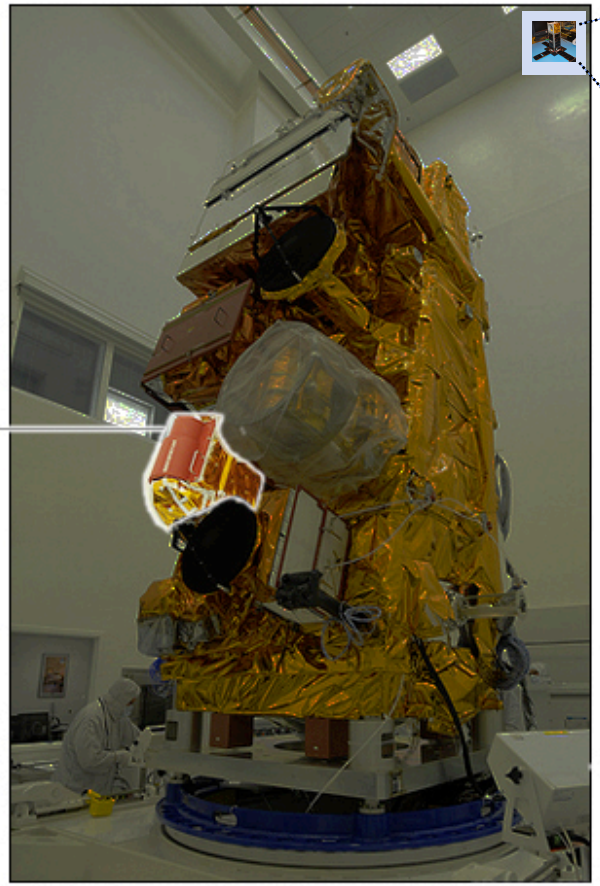
23.8-GHz Brightness Temperature (K)



- Microwave sensor amenable to miniaturization (10 cm aperture)
- Broad footprints (~50 km)
- Modest pointing requirements
- Relatively low data rate

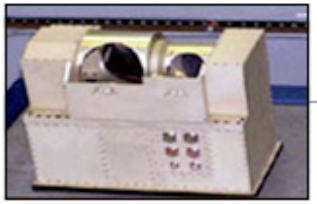
New Approach for Microwave Sounding

Suomi NPP Satellite (Launched Oct 2011)



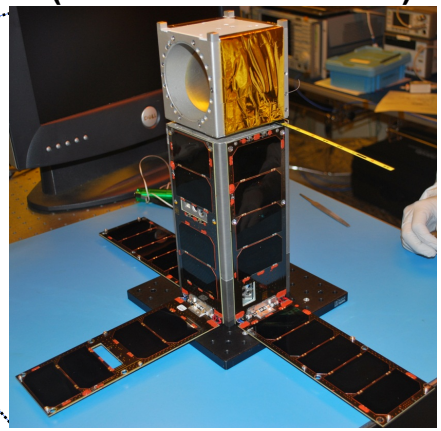
2100 kg NASA/GSFC

Advanced Technology Microwave Sounder (ATMS)



100 kg, 100 W

MicroMAS Satellite (Launched Jul 2014)



4.2 kg, 10 W, 34 x 10 x 10 cm

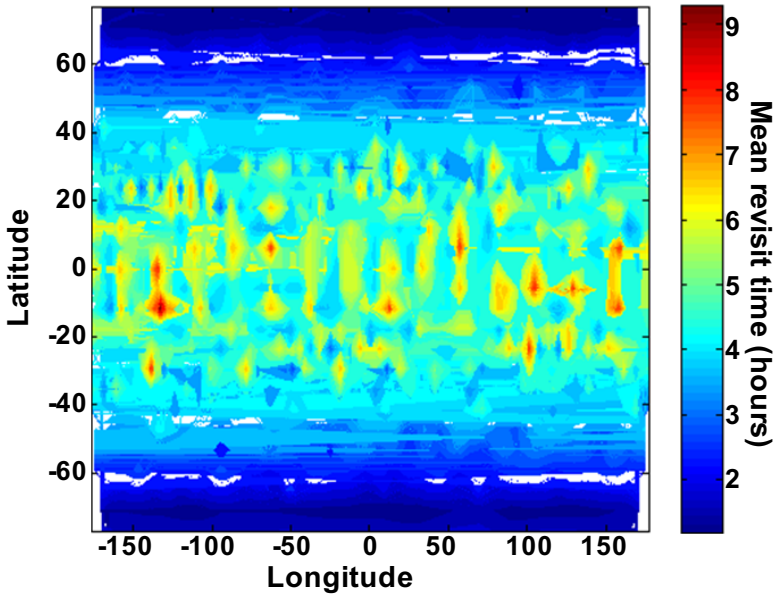
- **Microwave sensor amenable to miniaturization (10 cm aperture)**
- **Broad footprints (~50 km)**
- **Modest pointing requirements**
- **Relatively low data rate**

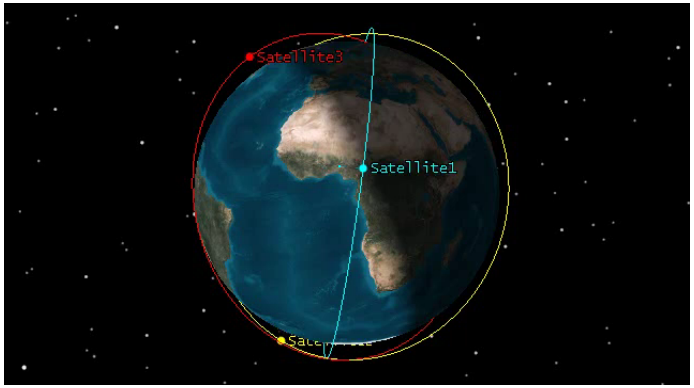
Perfect fit for a cubesat!

NPP: National Polar Partnership

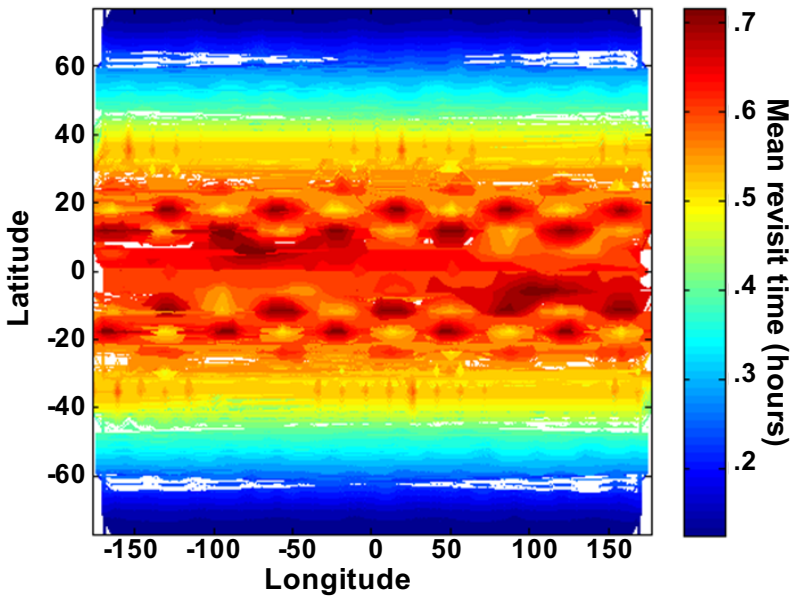
Architecture Studies Show Great Promise for Constellation Approaches

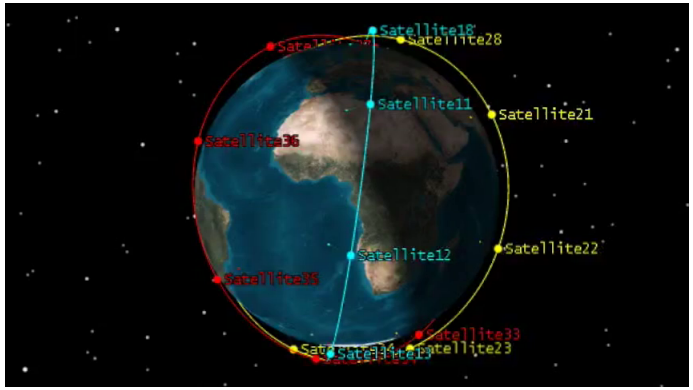
3 Satellites, one per plane



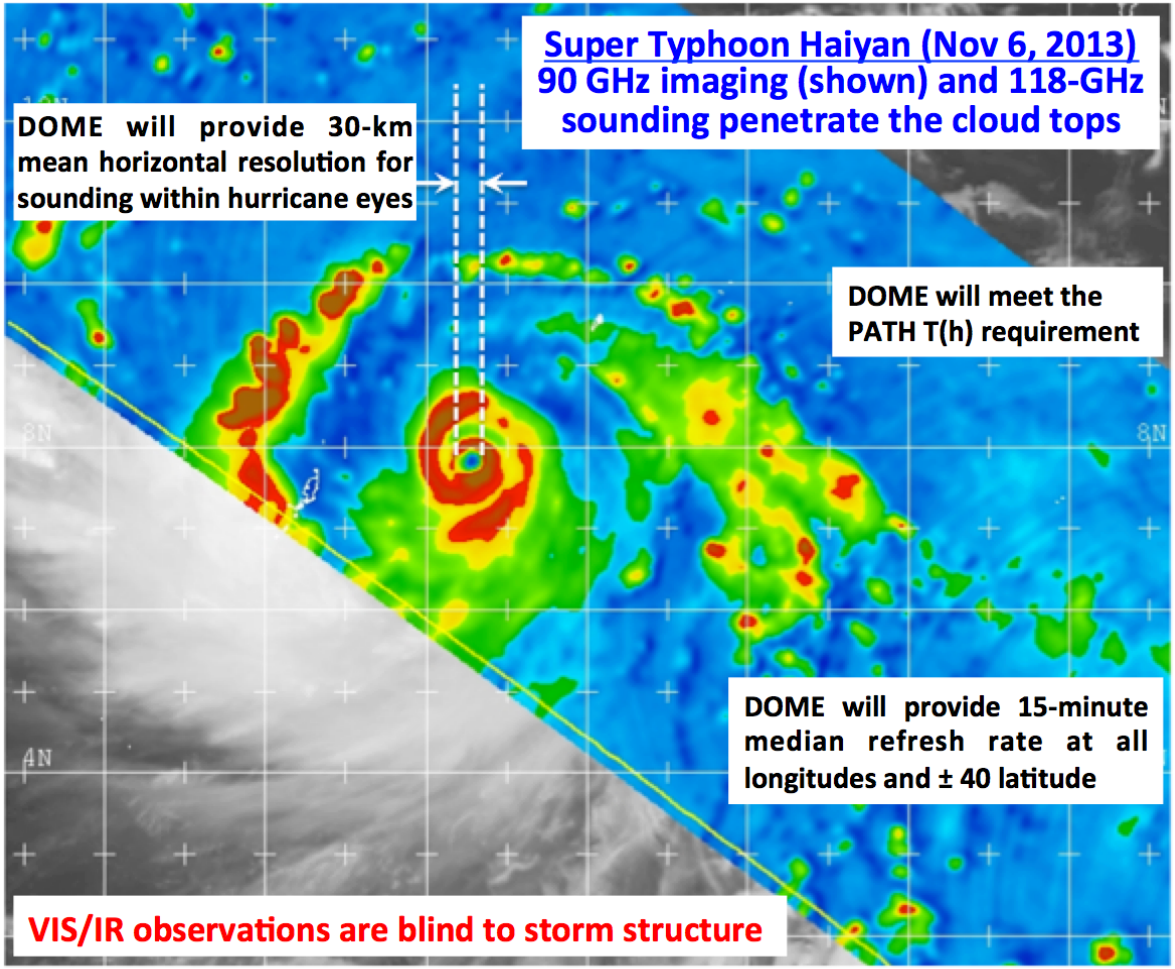


24 Satellites, eight per plane





DOME Constellation Concept



DOME = Distributed Observatory for Monitoring Earth (18 CubeSats)

Constellation Improves Forecast

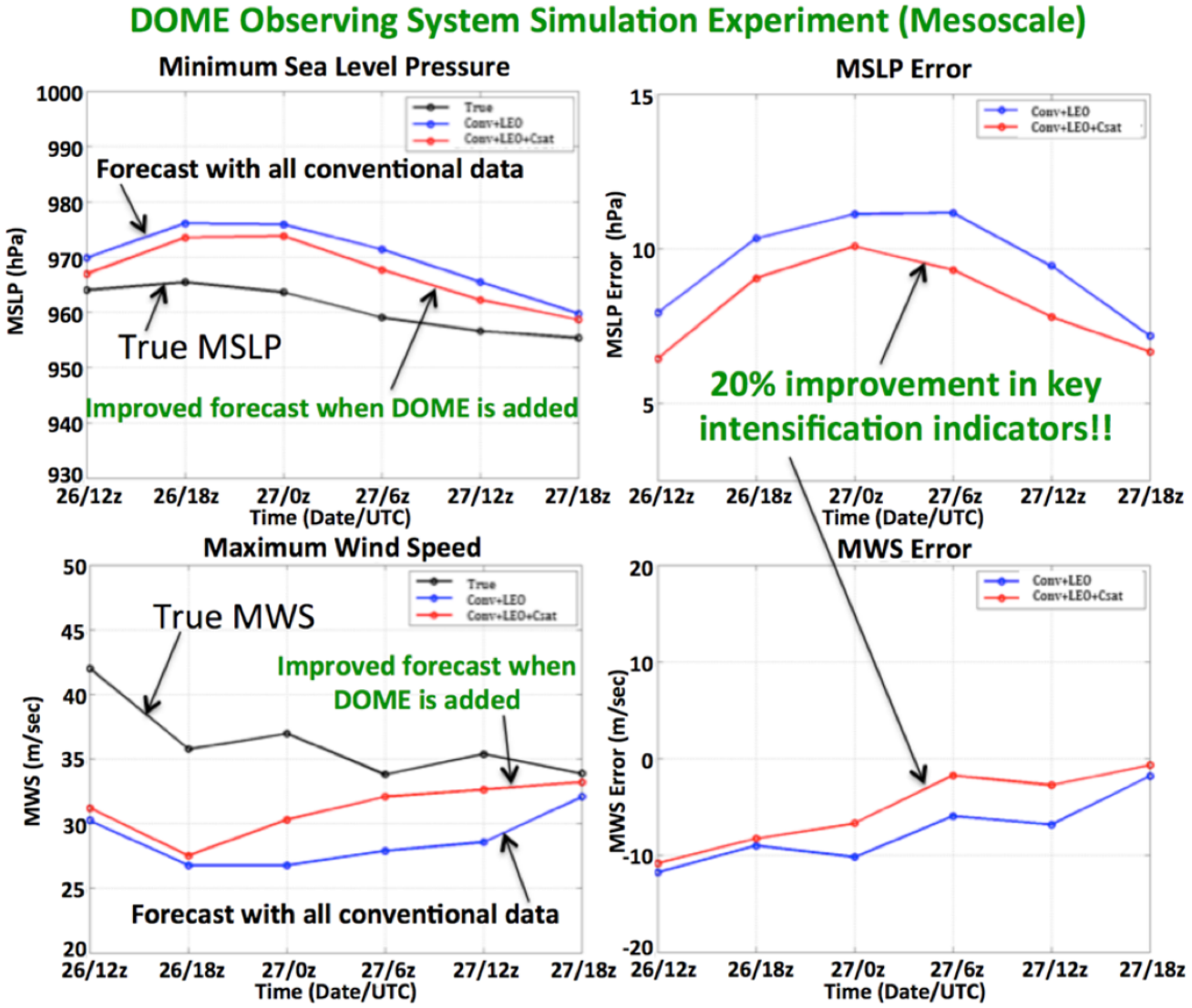


Figure credit: Jun Li, University of Wisconsin

Outline

- Introduction and Motivation
- **Radiometer Payload**
- **Spacecraft Bus Overview**
- Prelaunch Test and Validation
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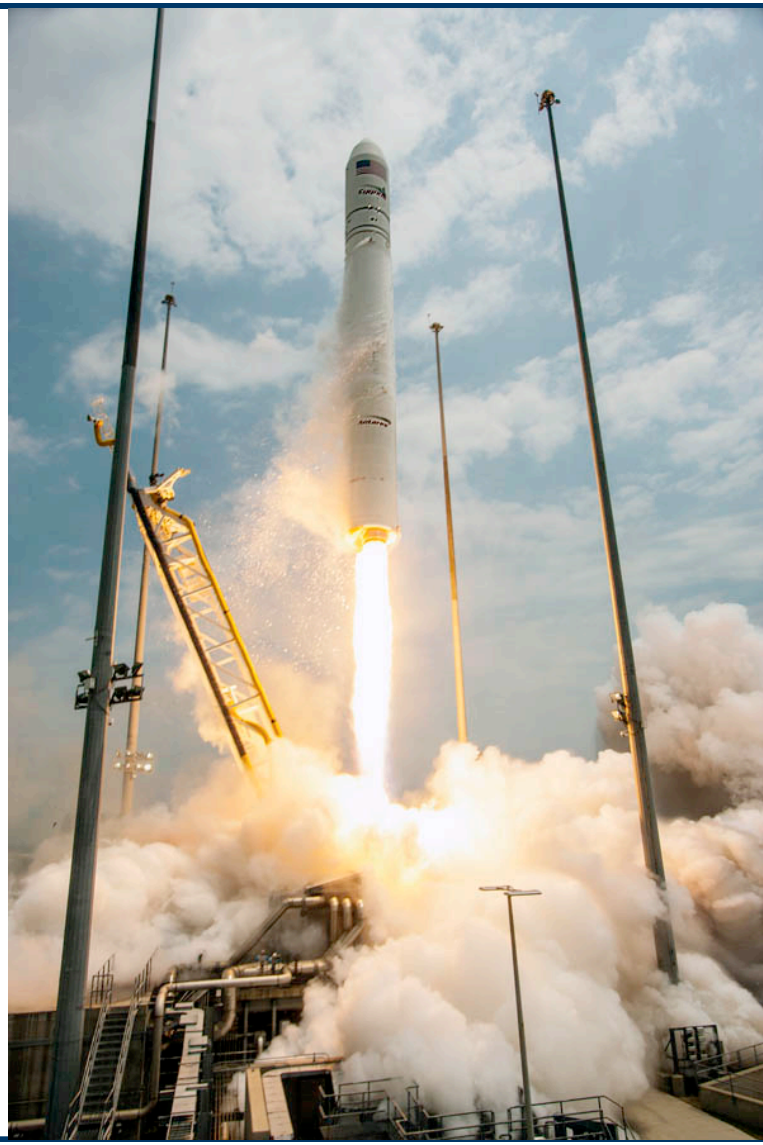
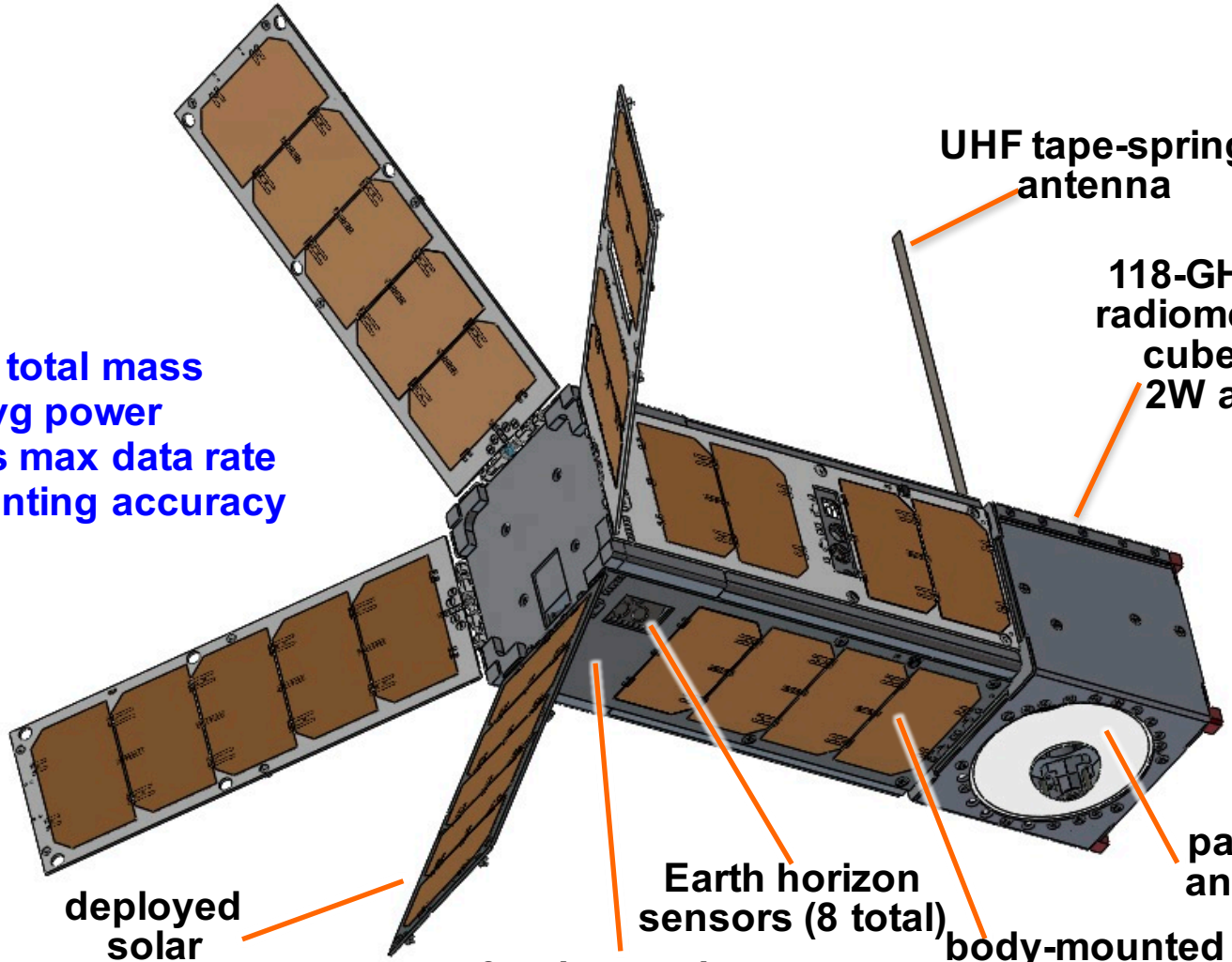


The MicroMAS CubeSat

- 4.25 kg total mass
- 10 W avg power
- 16 kbps max data rate
- 0.5° pointing accuracy



Measurement Requirements and Enabling Technologies

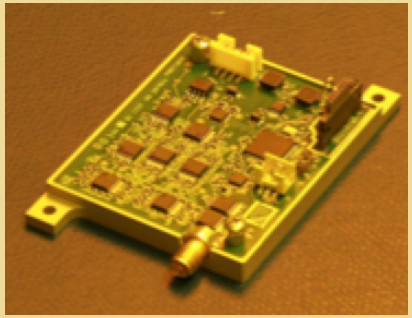
Temperature profile uncertainty of 2 K (RMS) in 50 km footprint needed to improve forecast accuracy

Six or more channels

Ultracompact spectrometer developed by Division 8

Low-temperature co-fired ceramic filters

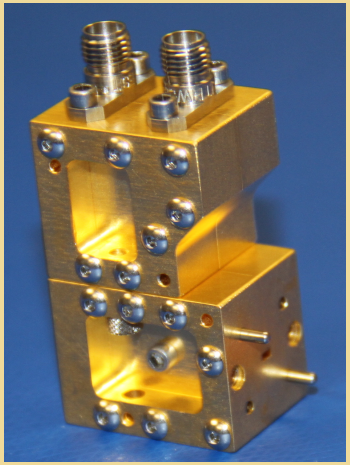
Operation from 18-29 GHz



Sensitivity better than 0.5 K (RMS)

Receiver front-end electronics developed by UMass-Amherst

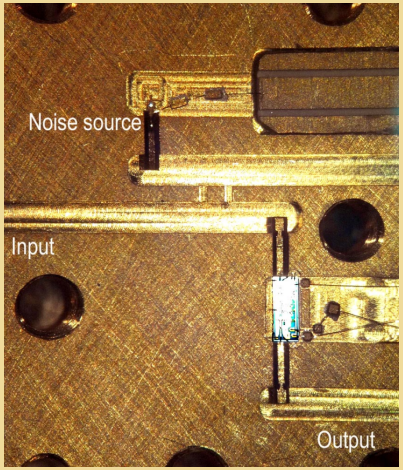
MMIC low-noise amplifiers and electronic calibration



Calibration accuracy better than 1 K (RMS)

Noise diode source provides periodic absolute calibration of radiometer

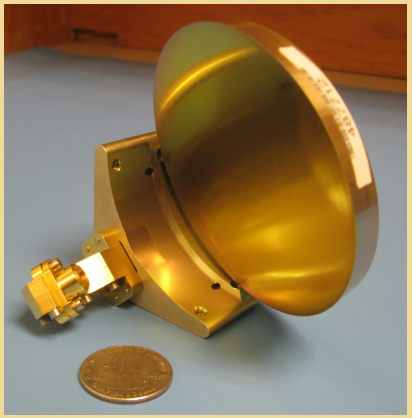
Highly stable; compact



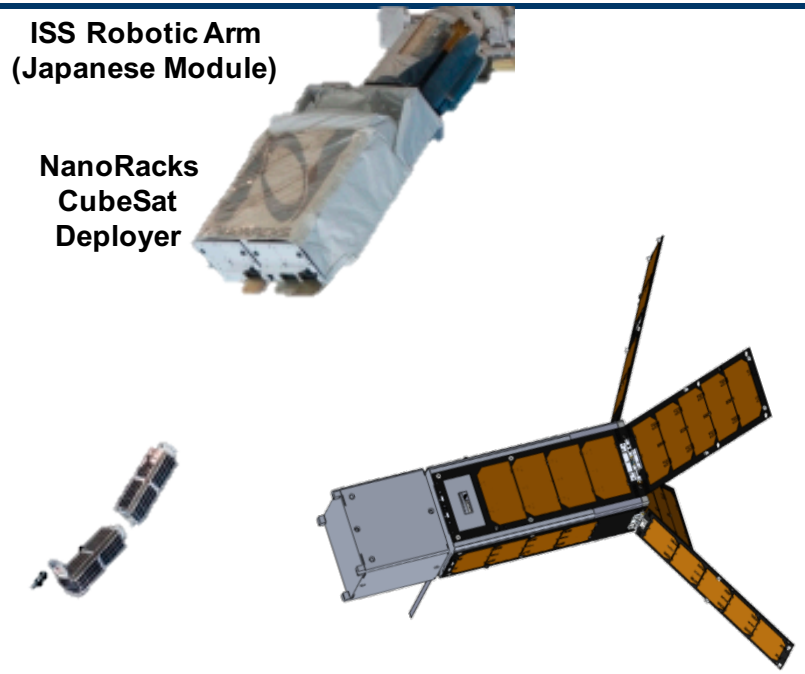
Aperture ~9 cm Beam efficiency > 95%

Offset parabolic reflector system with scalar feed

Lightweight, with 0.001" RMS surface tolerance



Micro-sized Microwave Atmospheric Satellite (MicroMAS)



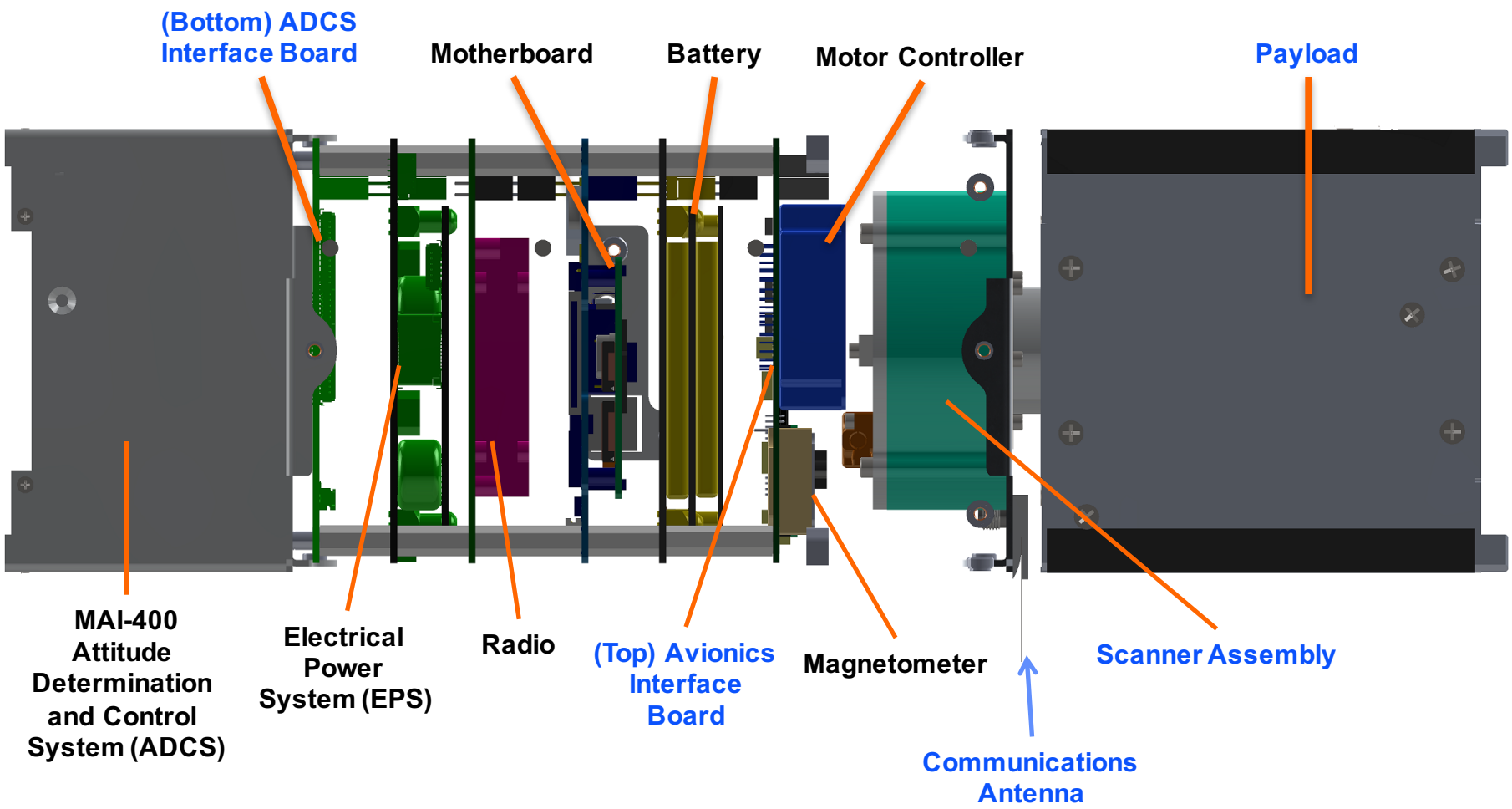
- 3U (10 cm x 10 cm x 34 cm) CubeSat
  - Cross-track scanning microwave spectrometer
  - Temperature and precipitation sensing
- July 13, 2014 launch ISS resupply mission
  - Deployed directly from ISS
  - 400 km, 52-degree inclination initial orbit
- UHF downlink to NASA Wallops Flight Facility
- Designed for a one year mission lifetime
  - Three month orbit decay from ISS release

Team MicroMAS

- MIT Lincoln Laboratory (Lead)
  - (Payload)
  - (I&T, SysEng, Controls support)
  - (Comm/Mission support)
- MIT Space Systems Lab (Bus)
- UMass-Amherst (RF receiver)
- NASA Wallops (Ground)

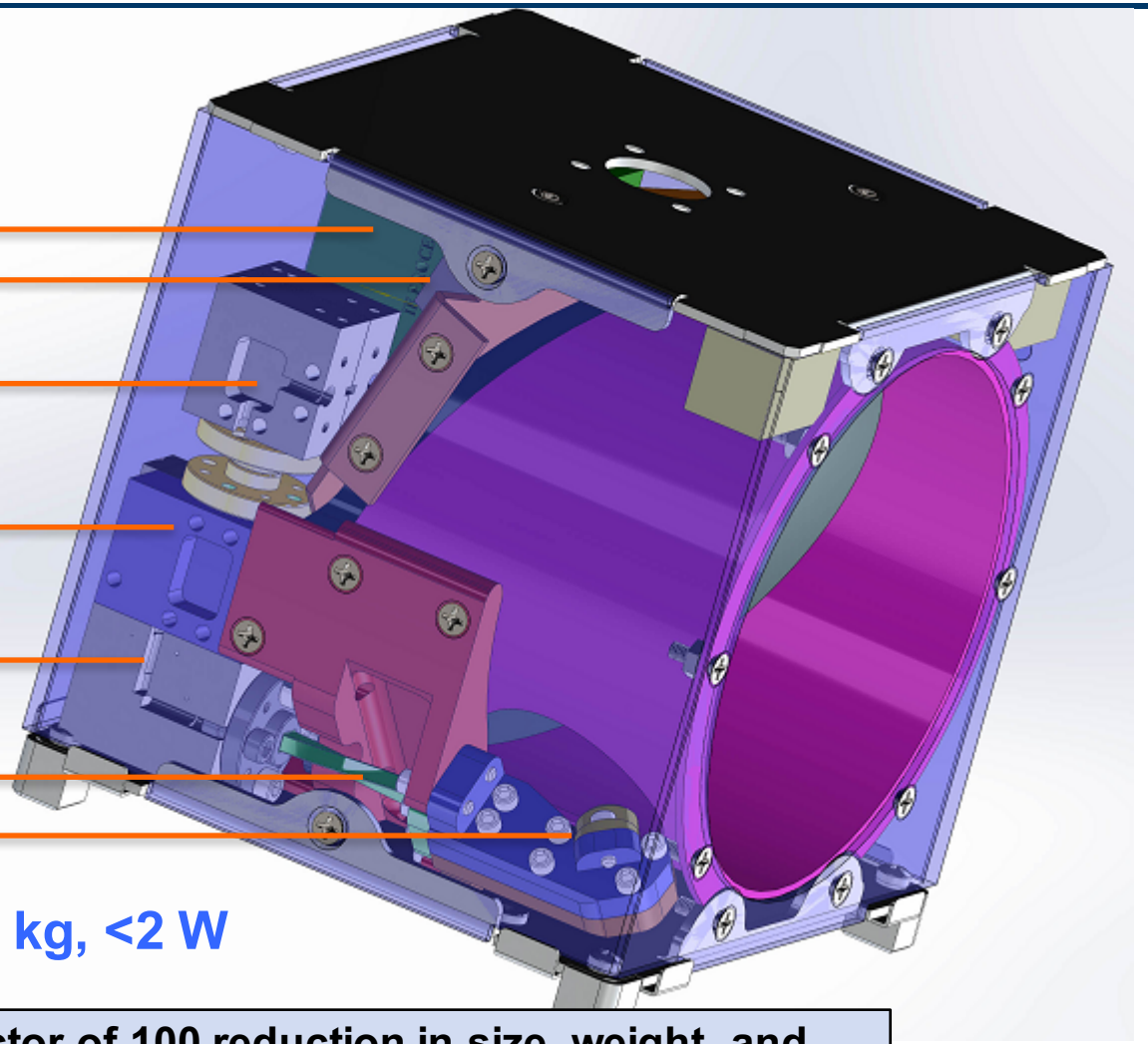
MicroMAS Bus Design

Custom vs. COTS Parts



Timely development of COTS parts was a major program challenge

MicroMAS Payload (Side View)
118-GHz Spectrometer

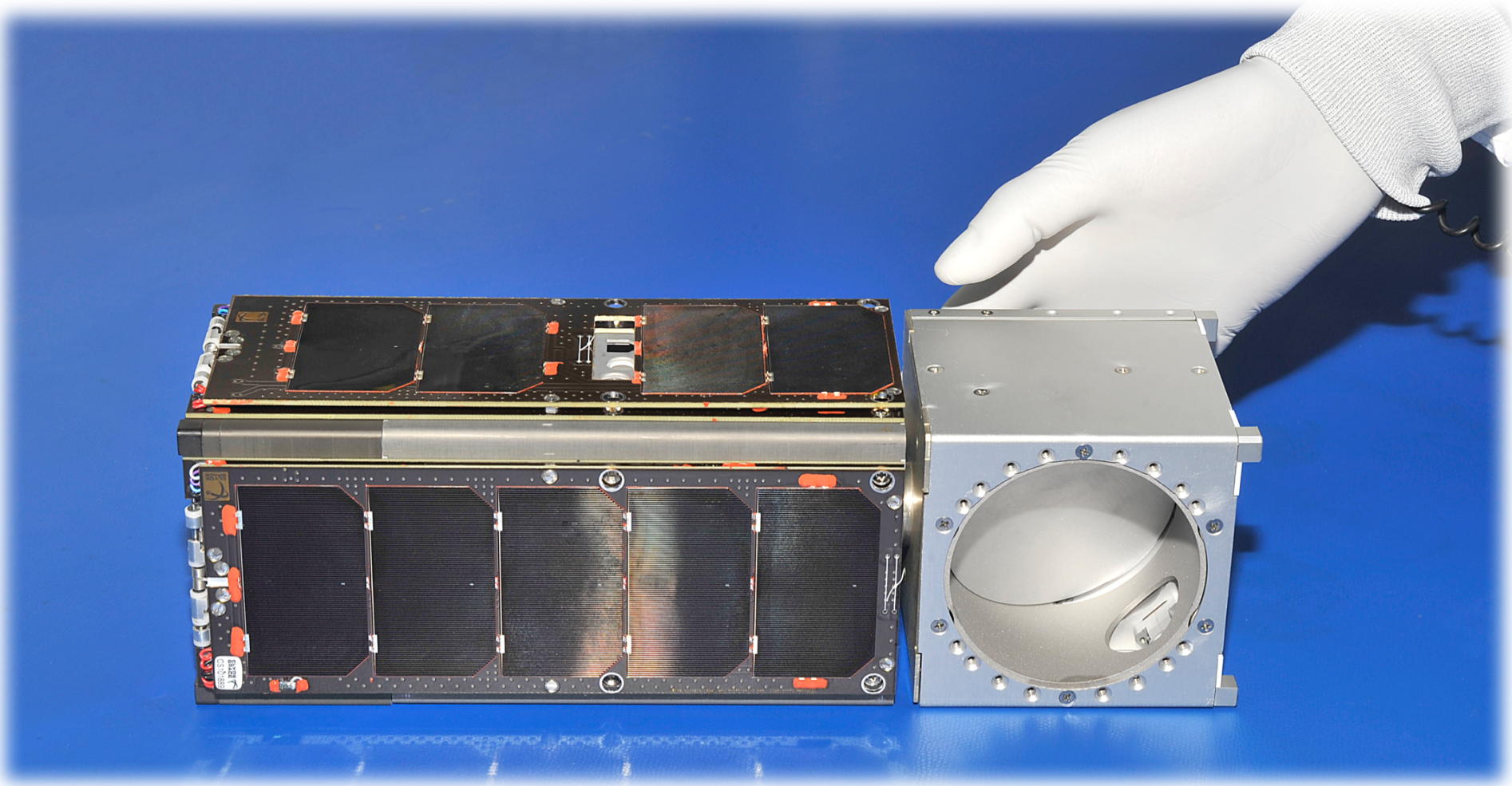


10x10x10 cm, <1 kg, <2 W

Approximately a factor of 100 reduction in size, weight, and power relative to the current state of the art

MicroMAS Assembly

MicroMAS Flight Unit



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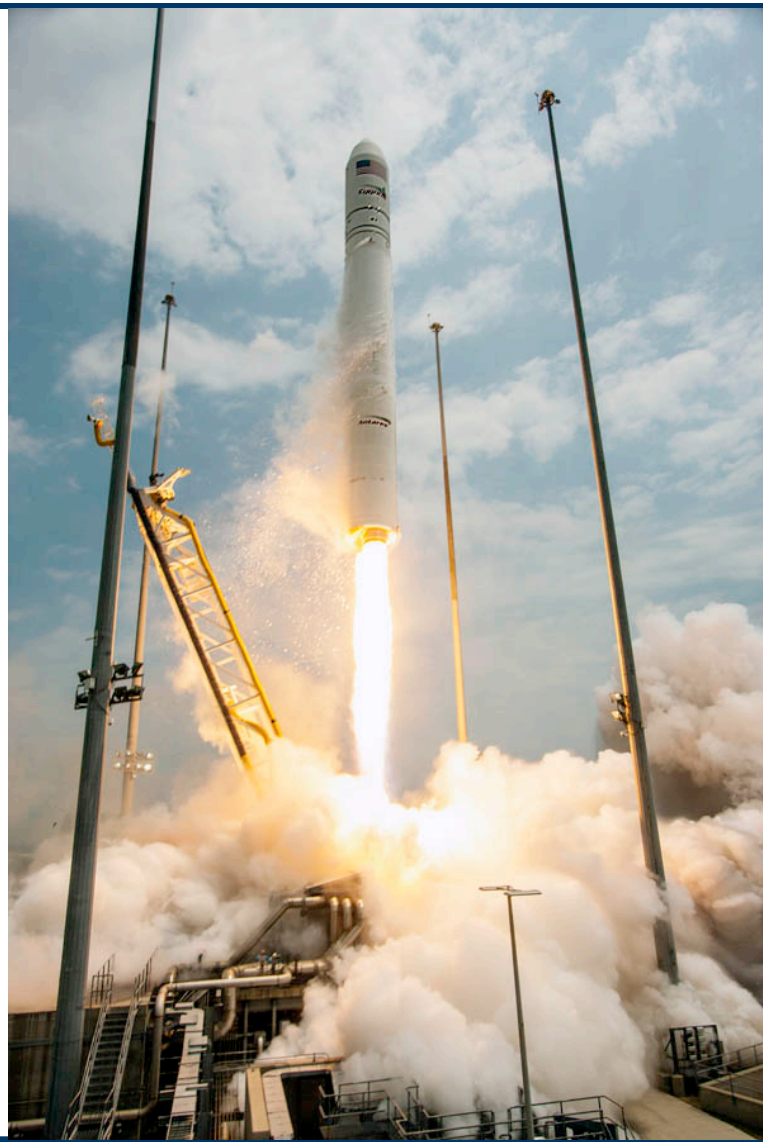
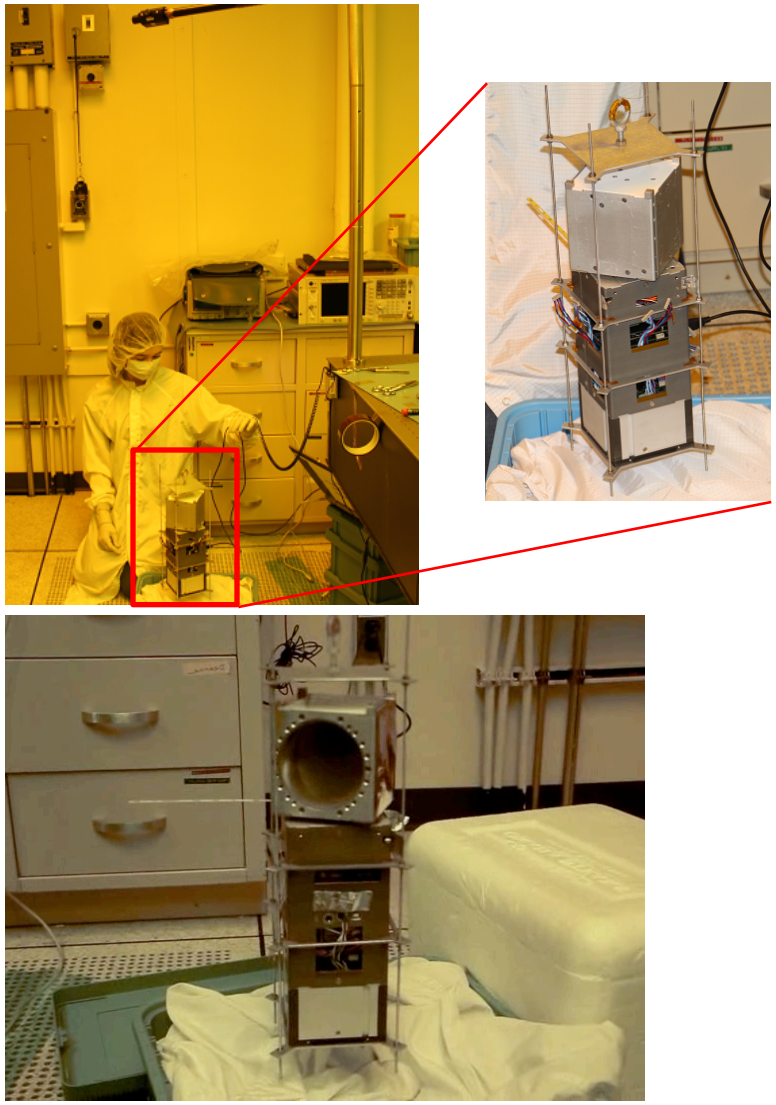
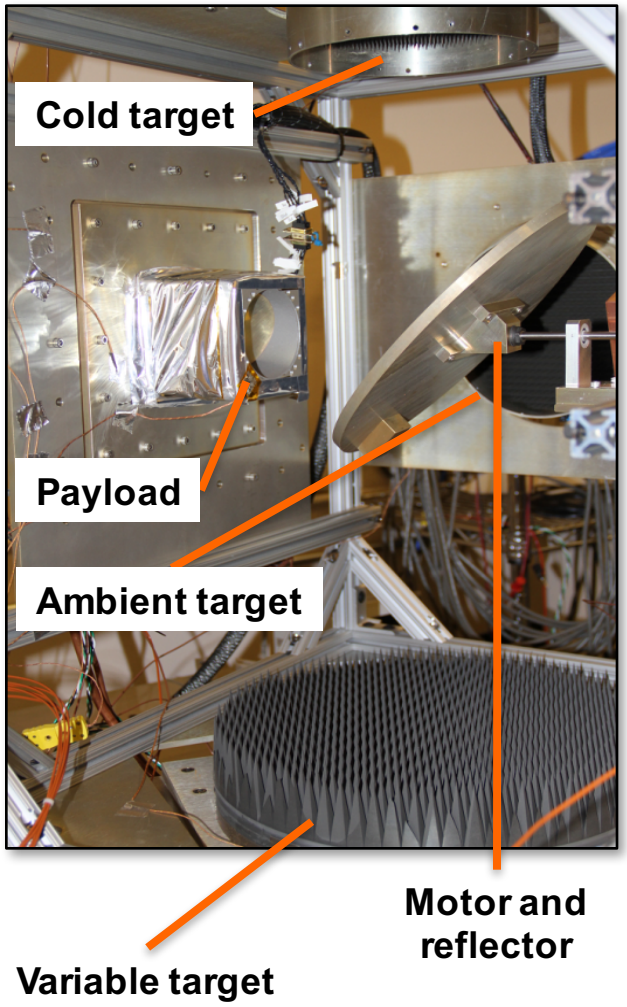


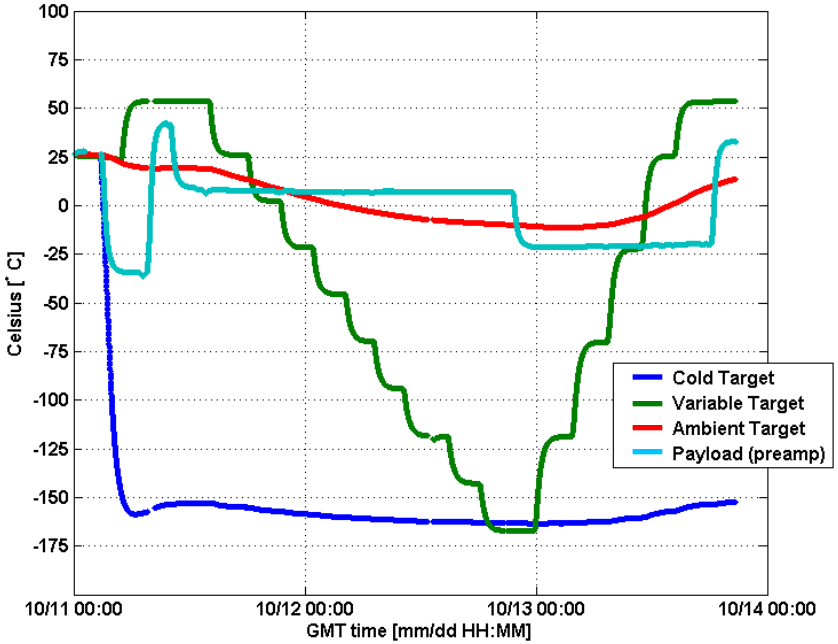
ADCS Software & Hardware Testing

- Development and testing of the Attitude Determination and Control System (ADCS) was a primary challenge
- Tests were devised to exercise all ADCS modes
  - Detumble
  - Slew
  - Payload spin-up
  - Stabilize
- Specialized test fixtures were developed to assess performance
  - Suspension assembly
  - Helmholtz cage
  - Air bearing



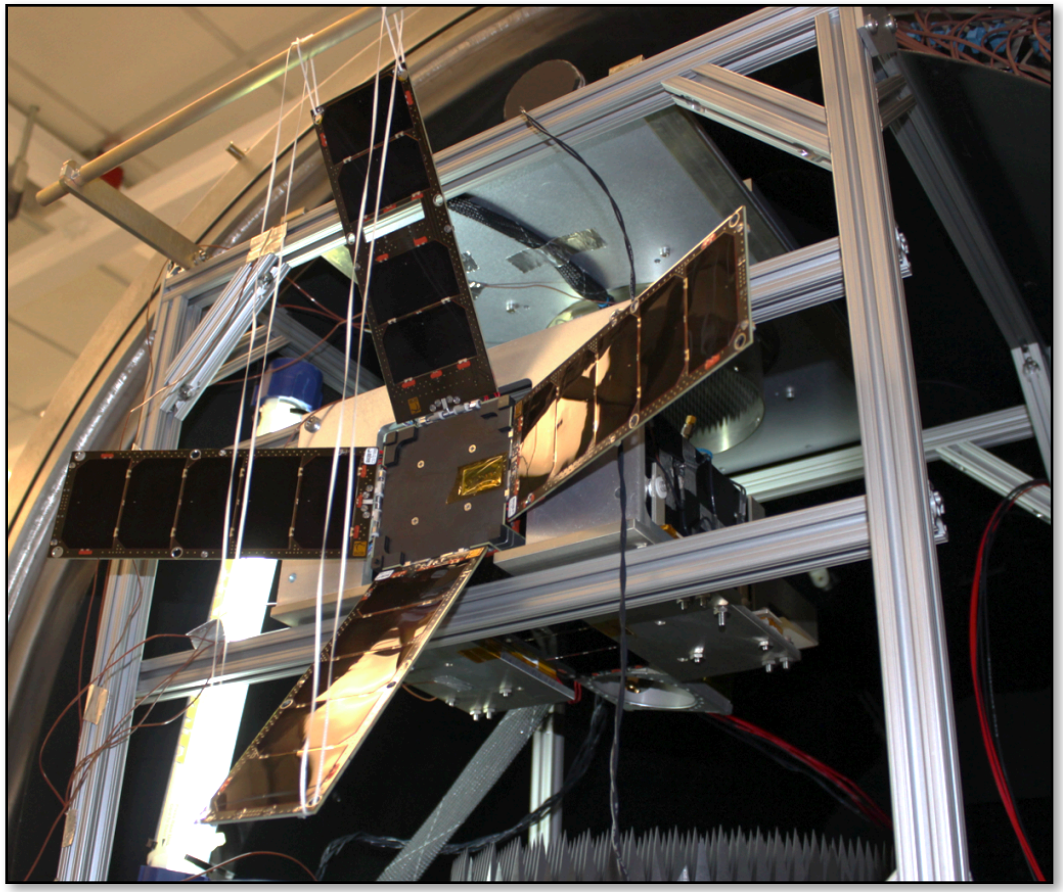
Payload TVAC for Radiometric Calibration





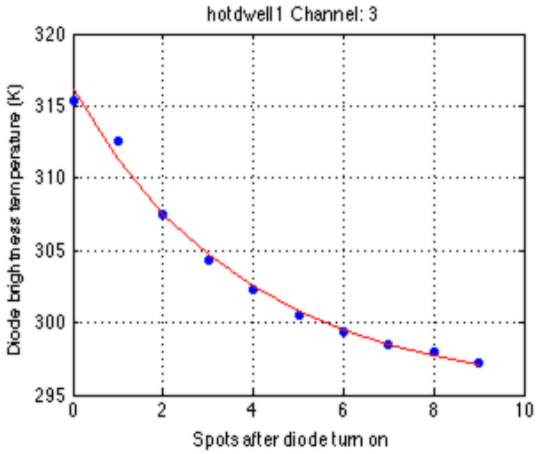
- Detailed simulations of payload thermal (cyan) and radiometric environment (red, green, blue)
- Assessments were made of:
  - Sensitivity
  - Absolute accuracy
  - Linearity
  - Stability

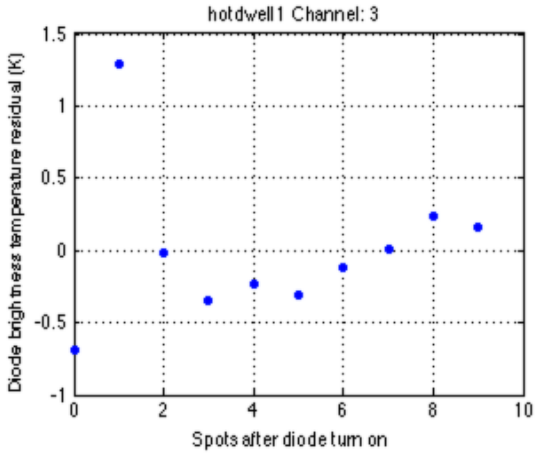
Space Vehicle TVAC

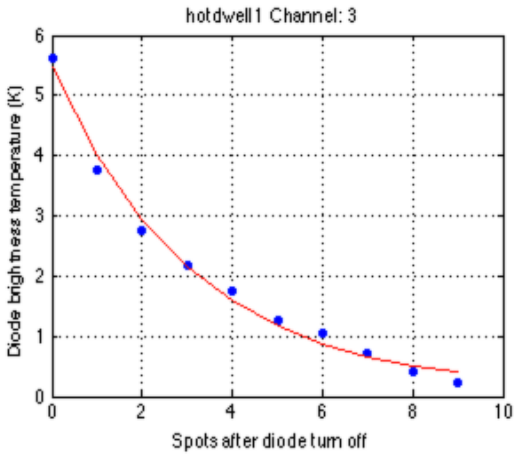


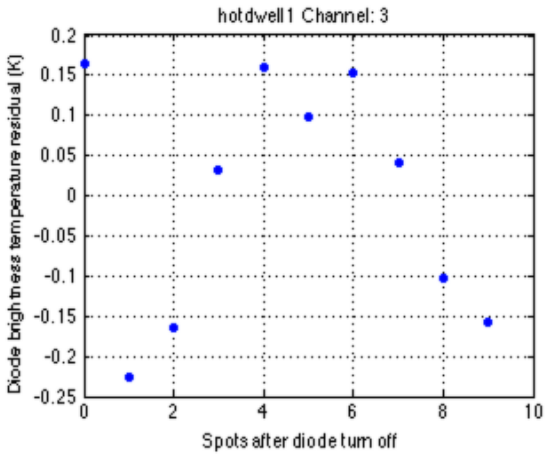
- A week of testing over a range of temperatures (-40 C to +50 C)
- Verified thermal model of spacecraft subsystems
  - Encoder operation at cold temperatures
  - Radio operation at hot temperatures
- Characterized the noise diode used for calibration

Noise Diode On/Off Transients

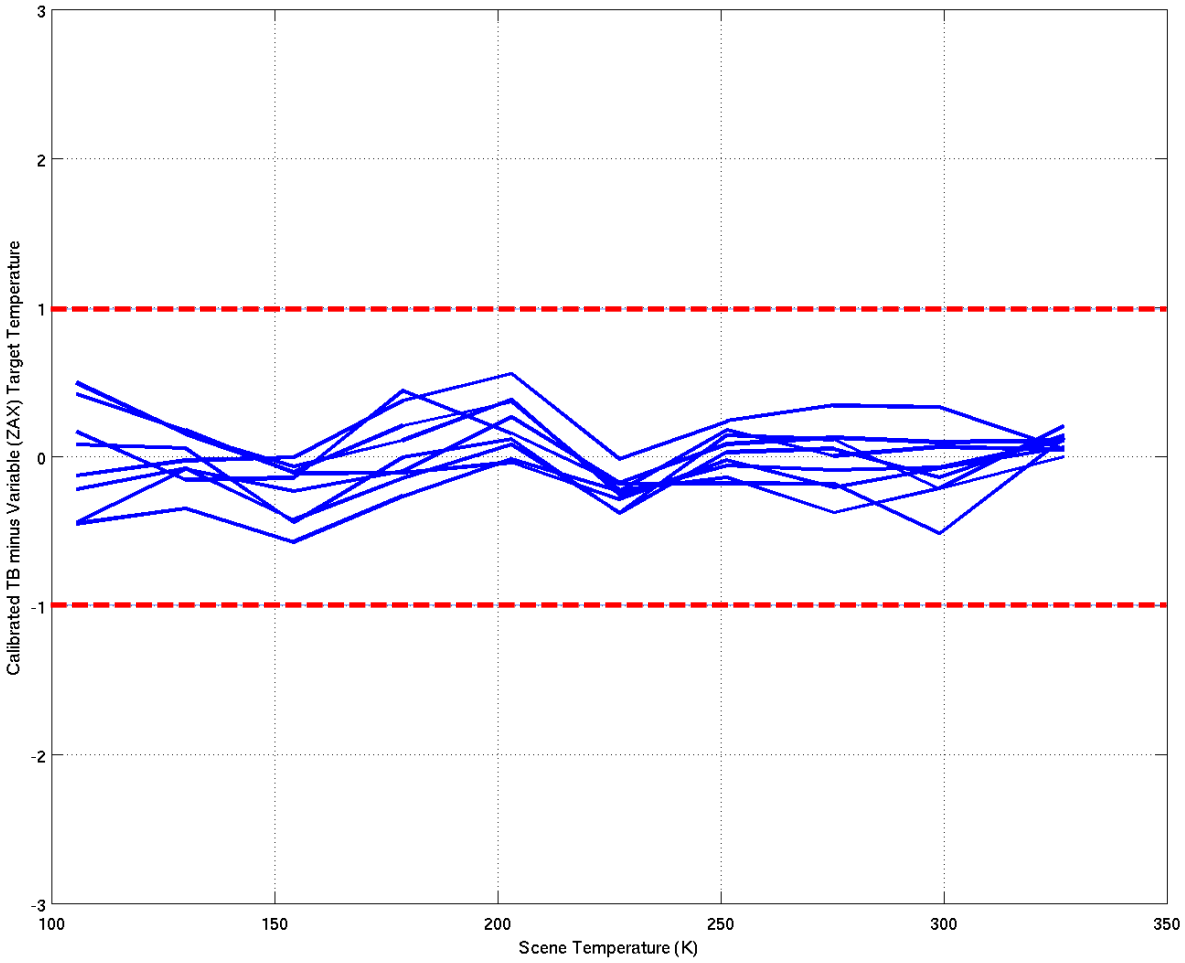






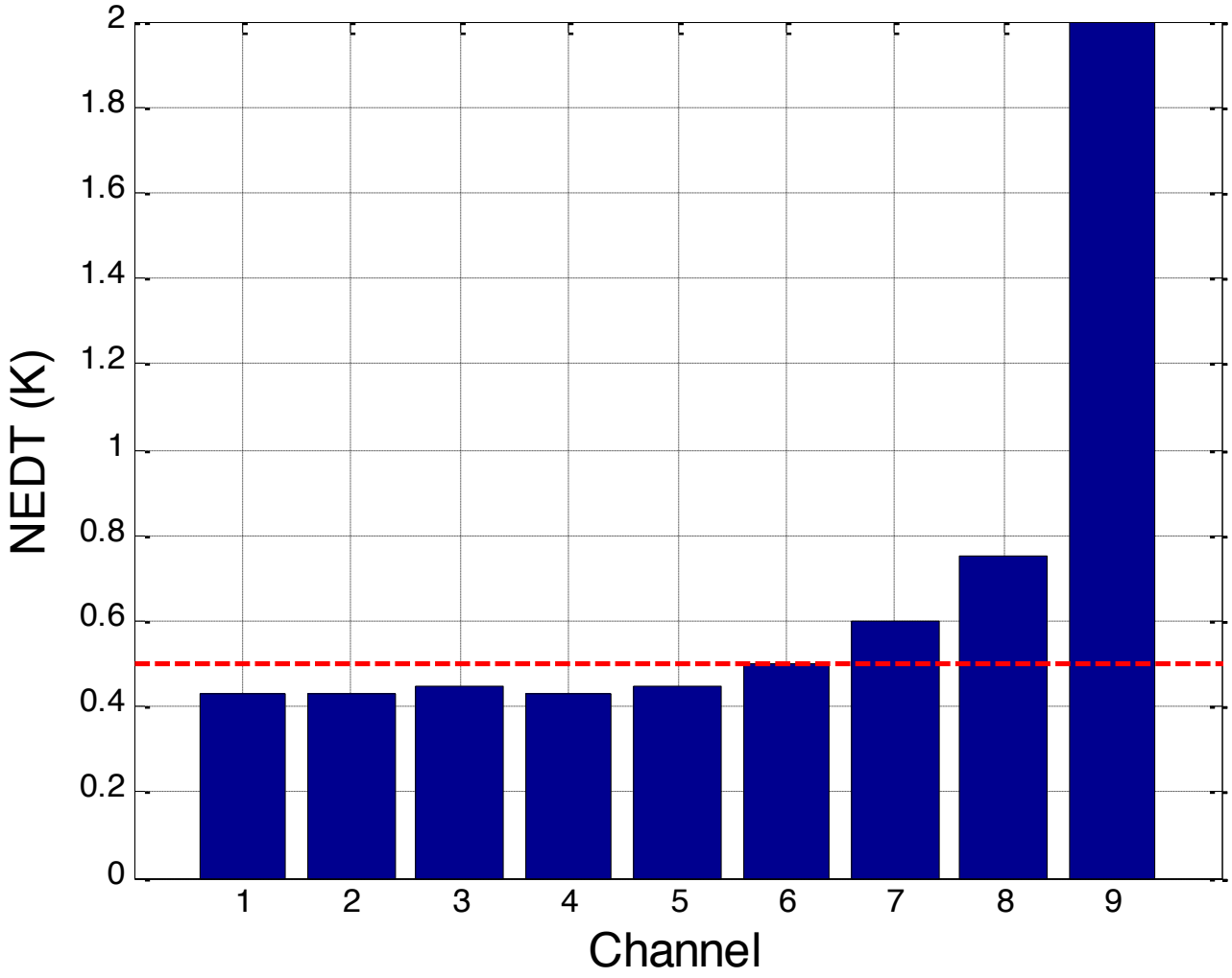


Accuracy Meets 1 K Requirement



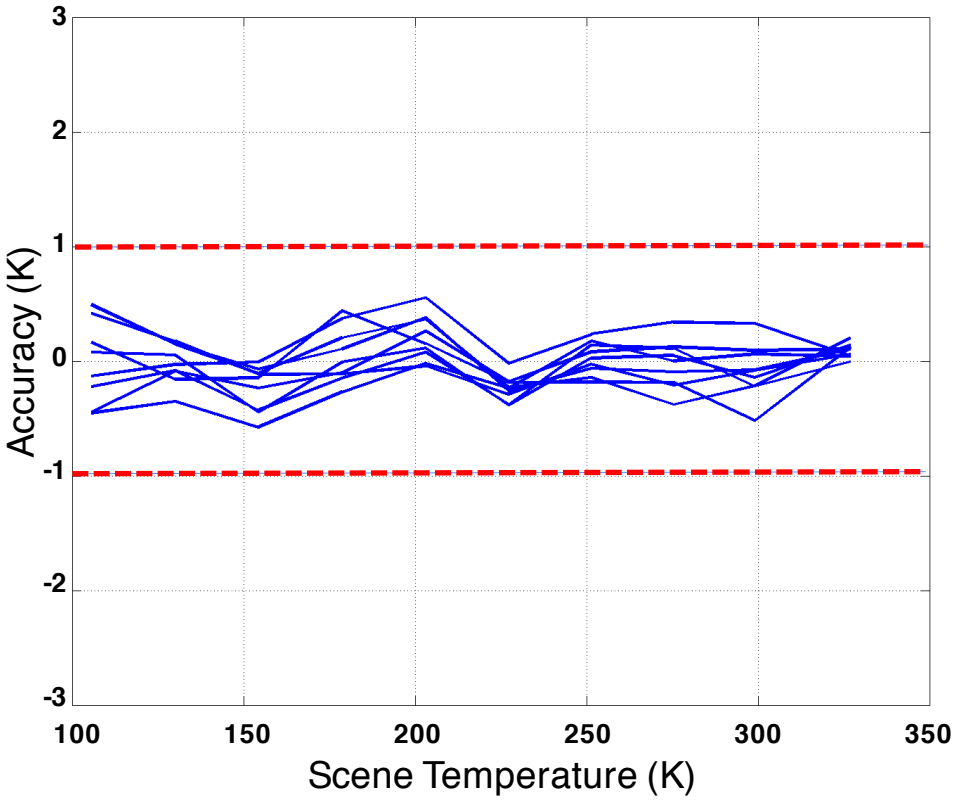
Bias corrections applied to external calibration targets

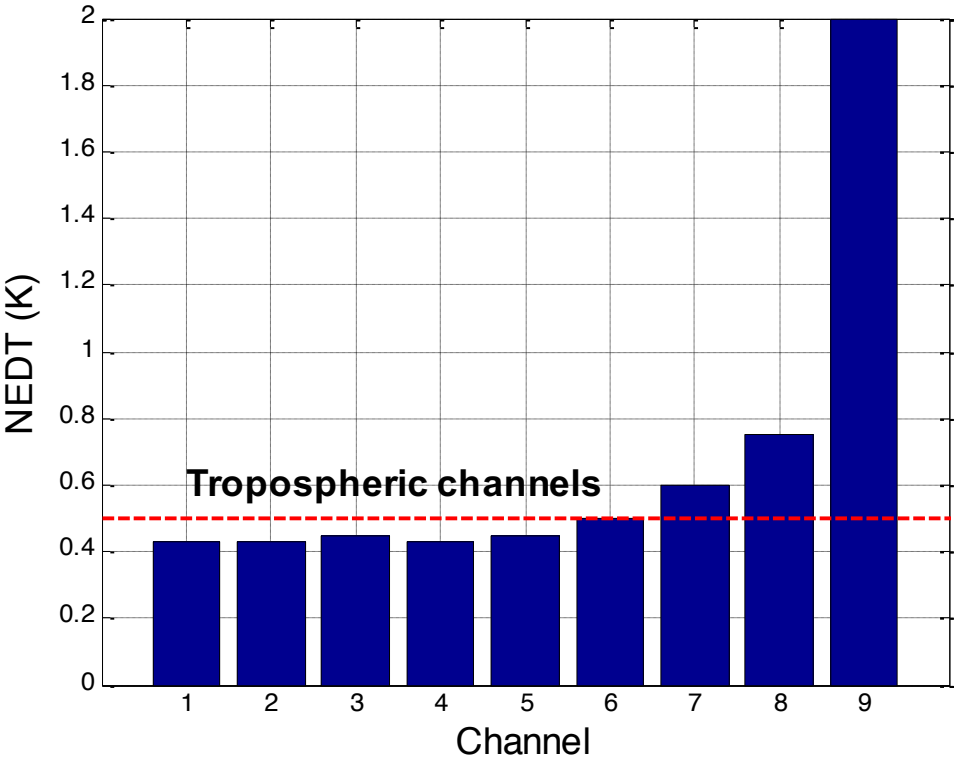
Sensitivity (NEDT) @ 300 K Scene



ATMS equivalent spot size; 250 K payload temperature

Radiometer Performance (Accuracy and Precision) is State-of-the-ART

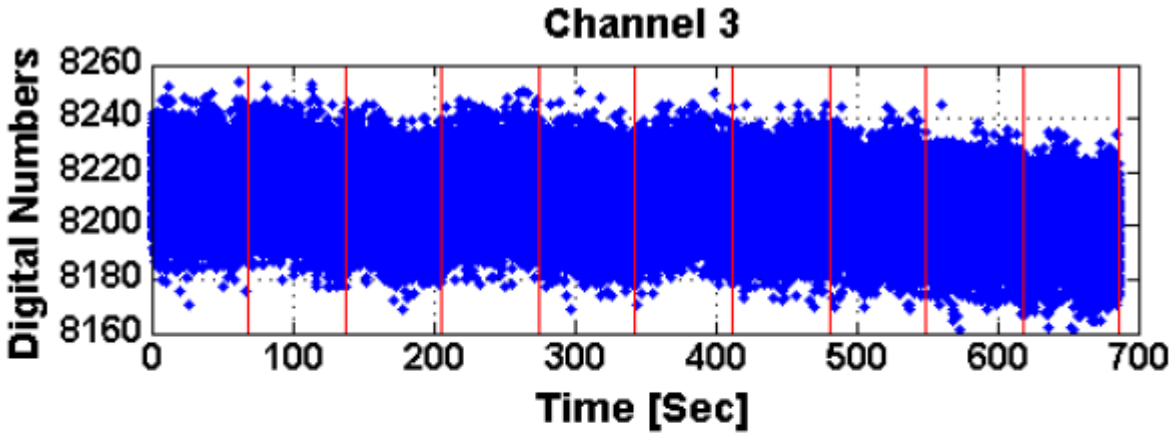


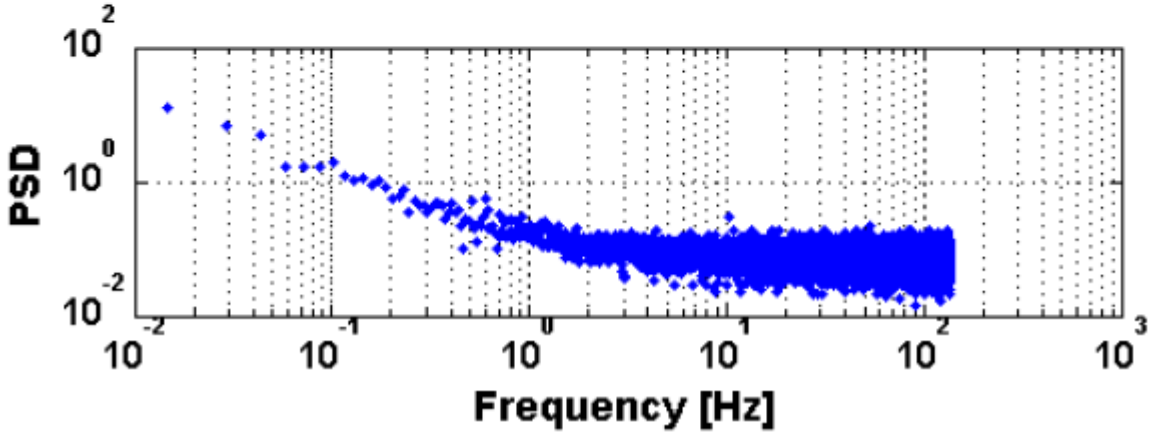


ATMS equivalent spot size; 250 K payload temperature

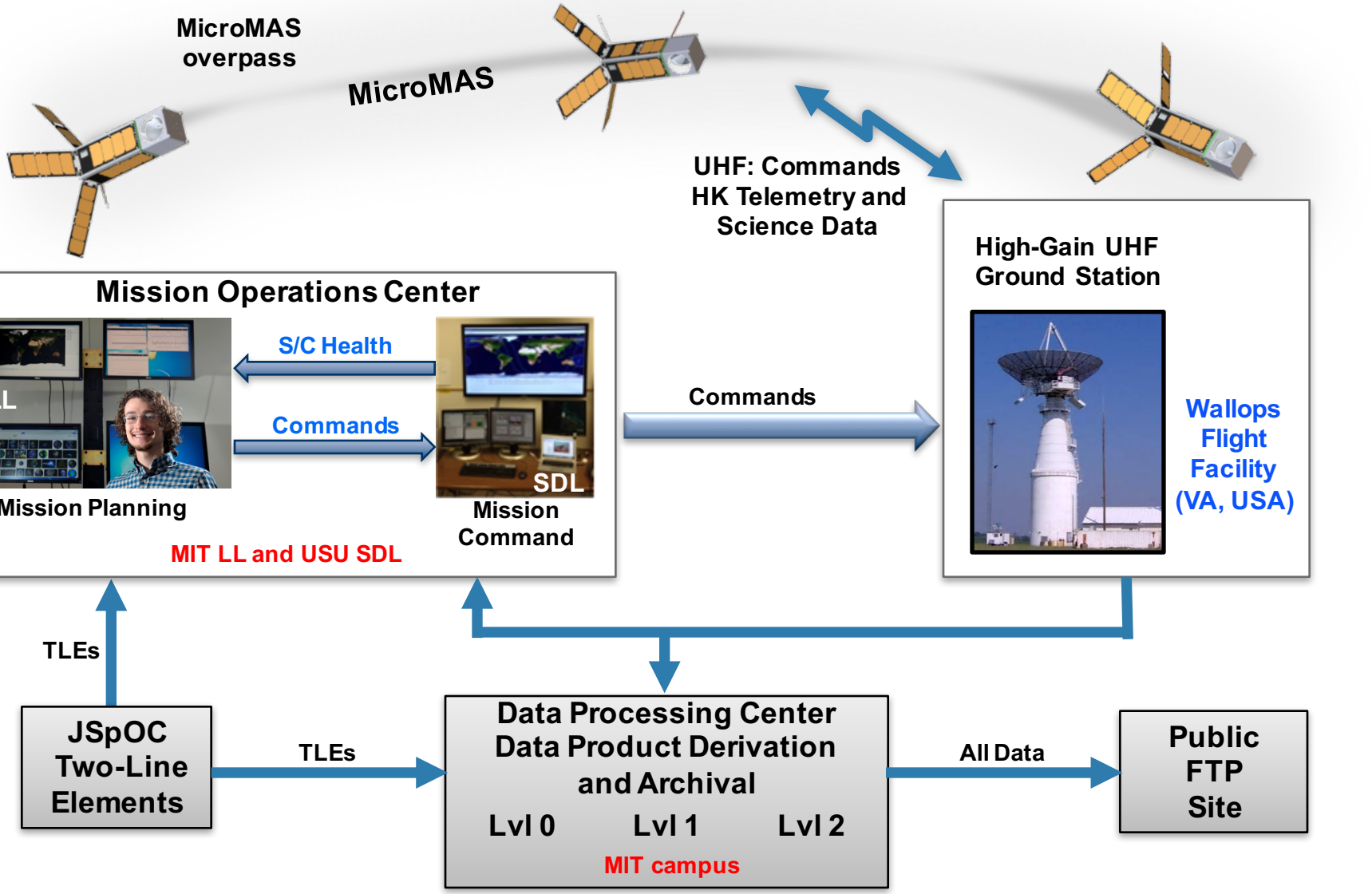
Power Spectral Density

- ~11 minutes of stare data separated into ~1.1 min. segments
- Averaged 10 FFTs (i.e., 10 segment)
- MicroMAS calibrated once every 0.75 sec

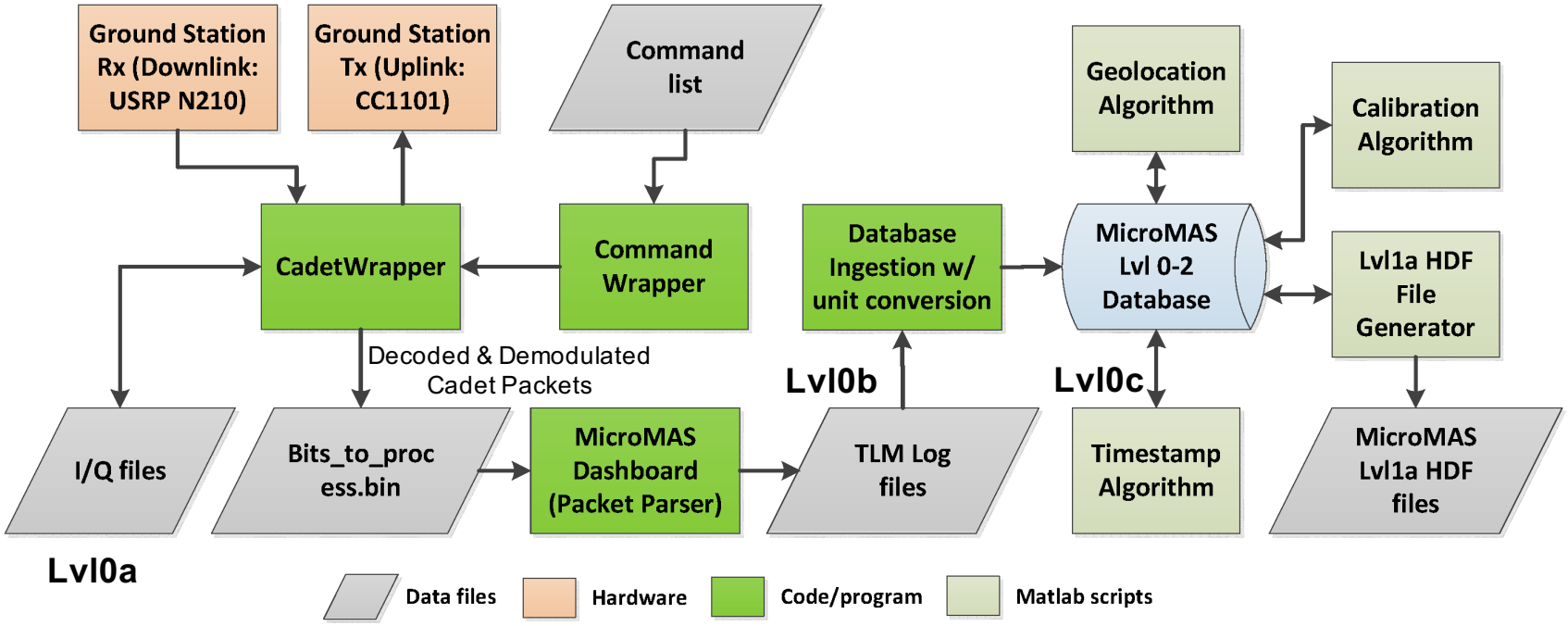




MicroMAS Ground & Data Segment



MicroMAS Operational Data Flowchart



Data Product	Description
Level 0a	Raw I/Q samples from USRP N210 containing L-3 Cadet packets
Level 0b	Stream of MicroMAS packets in Base64 log files
Level 0c	Ingested MicroMAS packets with units converted and timestamped
Level 1a	Calibrated & geolocated antenna temperatures at native resolution

Summary and Path Forward

- Nanosatellite sounding constellations could provide unprecedented performance at relatively low cost and risk
- MicroMAS will demonstrate a core element of the constellation
- Recent testing has indicated excellent performance
  - 40 RPM scanning; 2W payload power consumption
  - Accuracy and NEDT meet requirements
- July 13, 2014 launch
- Deployment from ISS via Nanoracks in early September
- 468 MHz downlink frequency (OQPSK, 3-MHz bandwidth)

- Microwave Radiometer Technology Acceleration (MiRaTA)
  - Next generation follow-on with multiple bands (temp. and water)
  - 2016 launch (poster on Wed afternoon)