The Microwave Accelerometer Technology Acceleration CubeSat (MiRaTA)

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This work is sponsored by the National Oceanic and Atmospheric Administration under Air Force Contract FA8721-05-C-0002. Opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the United States Government.

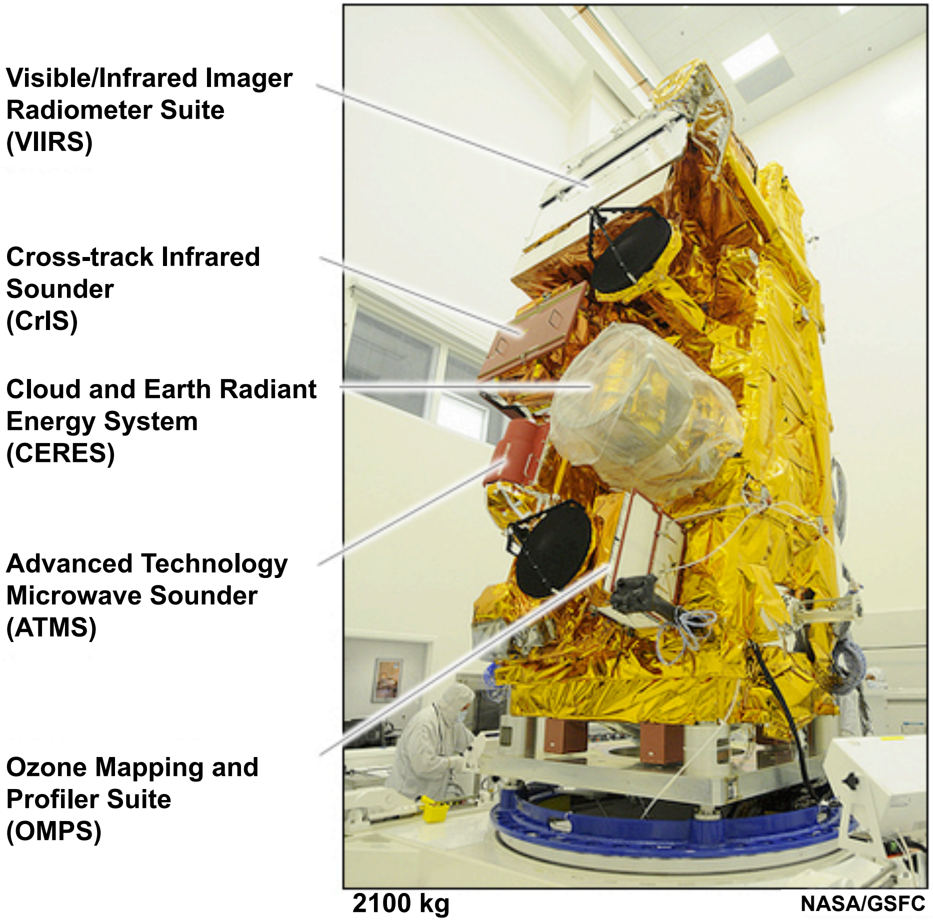
Outline

- **Introduction and Motivation**
- MicroMAS CubeSat
  - *Microsized Microwave Atmospheric Satellite*
- MiRaTA CubeSat
- MiRaTA Status
- Summary

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

Traditional Approach: Big Satellites

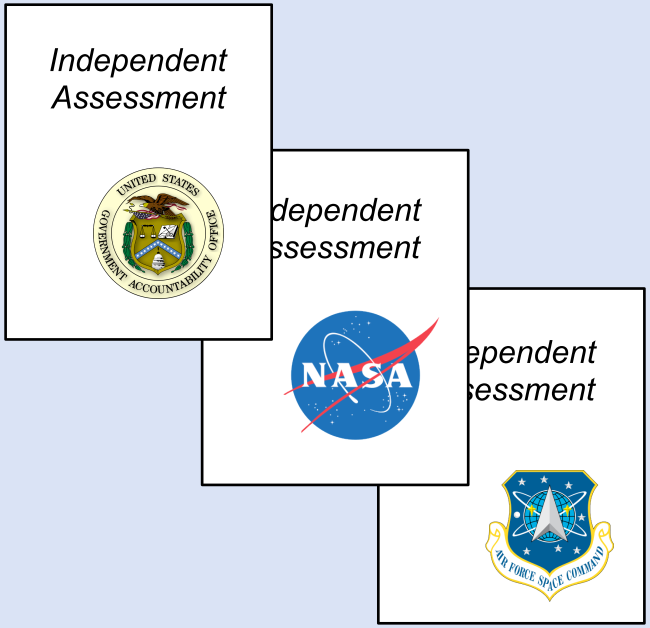
Suomi NPP Satellite
(Launched Oct. 2011)



NPP: National Polar Partnership

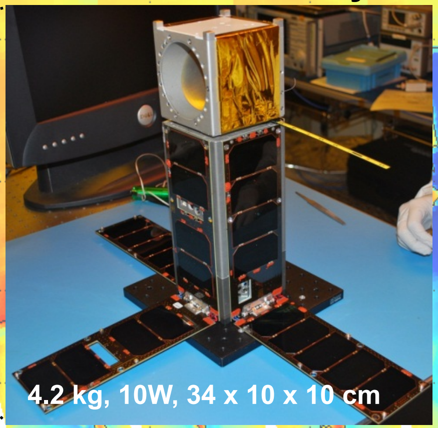
Current Approaches Unsustainable

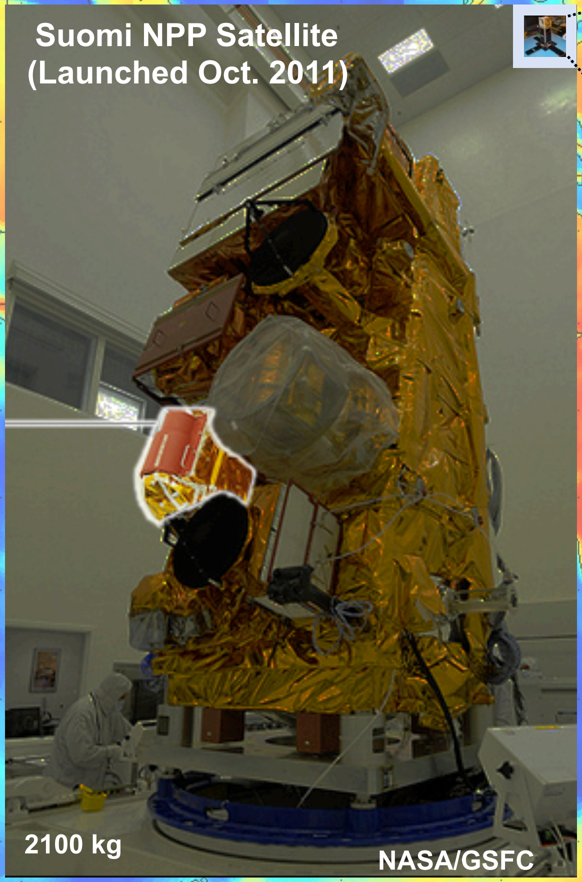
- **Expensive**
- **Long development cycles**
- **Very high failure impact**



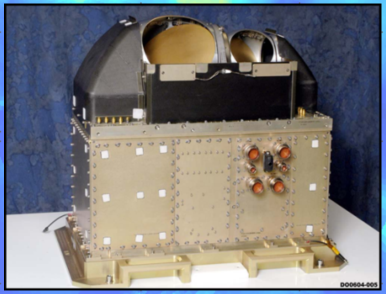
New Approach for Microwave Sounding

MicroMAS Satellite
(Launched to ISS July 2014)





Advanced Technology Microwave Sounder (ATMS)



100 kg, 100 W

- 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-orbiting Partnership

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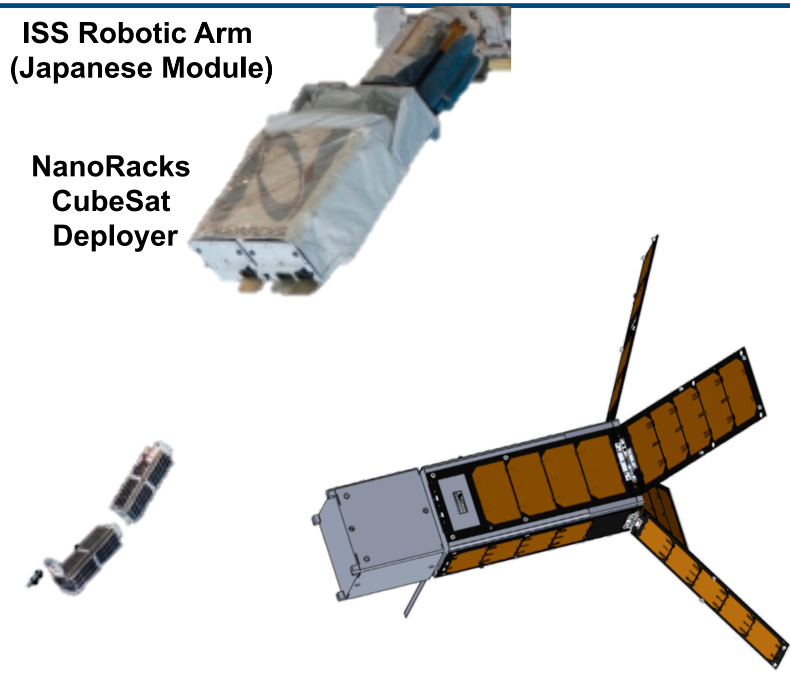
Micro-sized Microwave Atmospheric Satellite (MicroMAS)



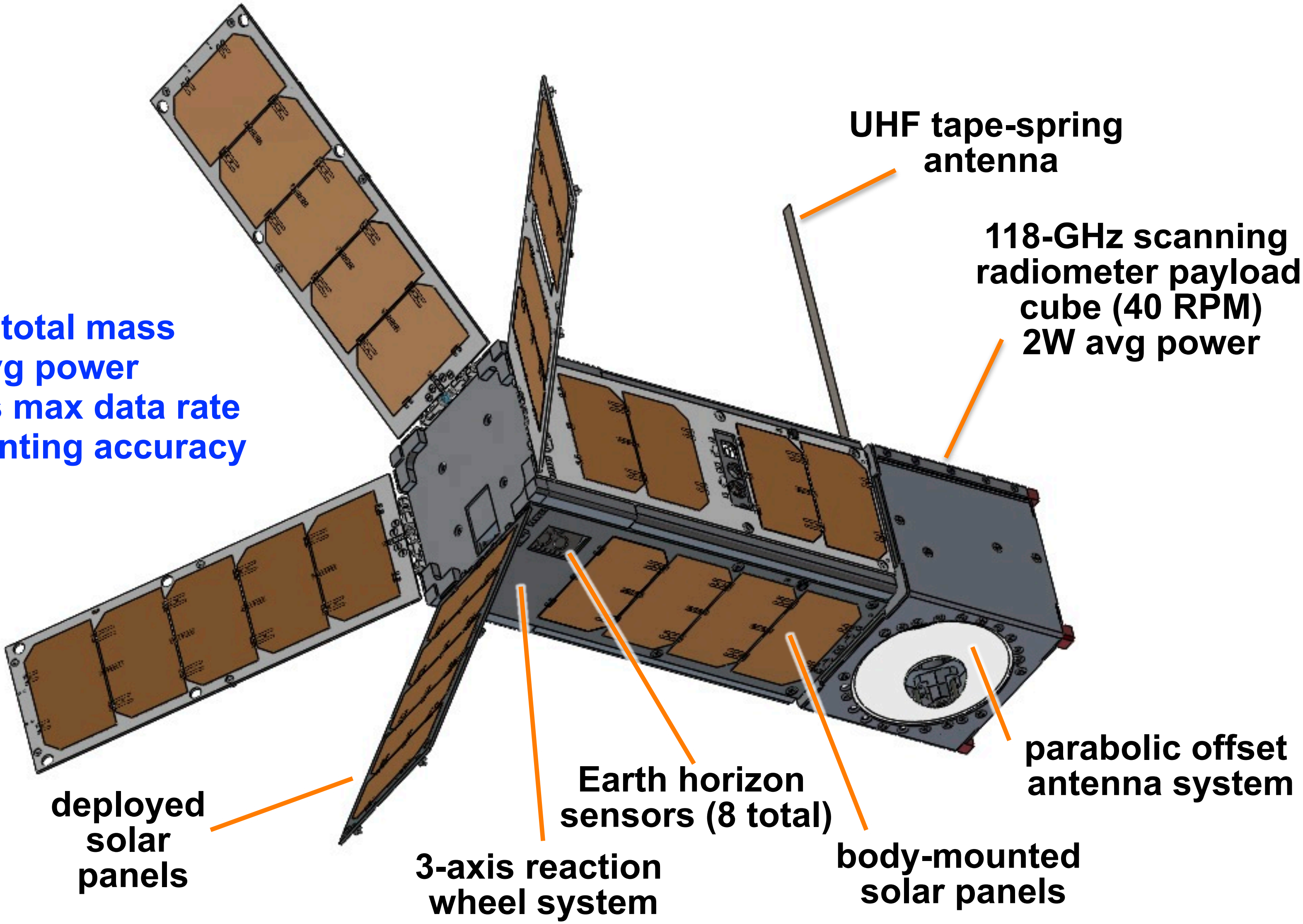
- 3U (10 cm x 10 cm x 34 cm) CubeSat
  - Cross-track scanning microwave spectrometer
  - Temperature and precipitation sensing
- July 13, 2014 launch ISS resupply mission
  - Will deploy directly from ISS
  - 400 km, 52-degree inclination initial orbit
- UHF downlink to NASA Wallops Flight Facility
-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

Team MicroMAS

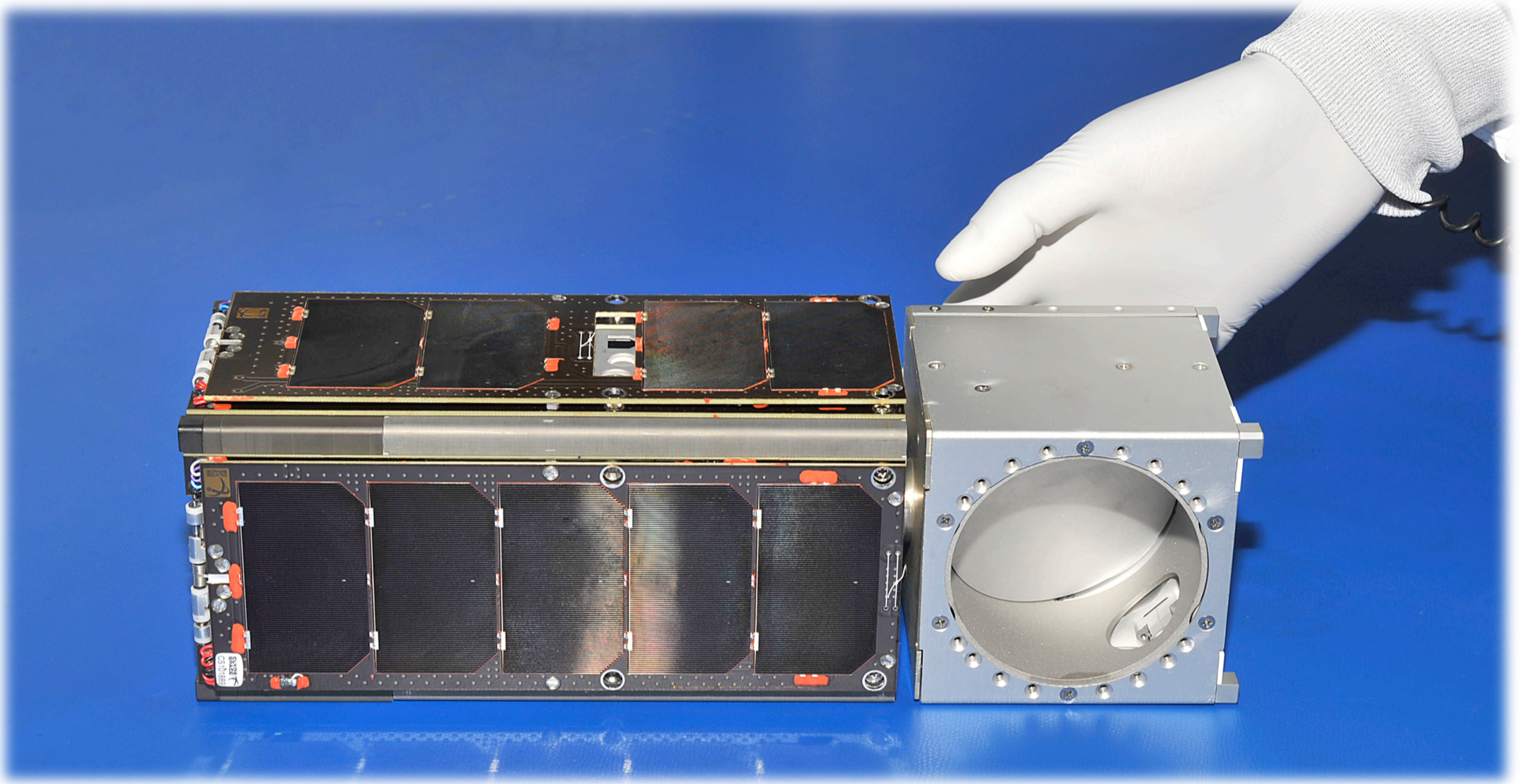
- MIT Lincoln Laboratory (Lead)
  - (Payload)
  - (I&T, SysEng, Controls support)
  - (Comm/Mission support)
- MIT Space Systems Lab (Bus)
- UMass-Amherst (RF receiver)
- NASA Wallops (Ground)
- USU SDL (Mission & Ground)

The MicroMAS CubeSat

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



MicroMAS Flight Unit



Measurement Requirements and Enabling Technologies

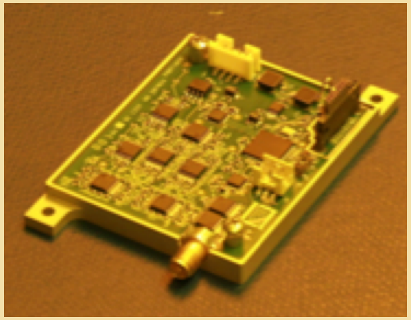
Temperature profile uncertainty of 2 K (RMS) in 50 km footprint needed to improve forecast accuracy

Six or more channels

Ultracompact spectrometer developed by Division 8

Low-temperature co-fired ceramic filters

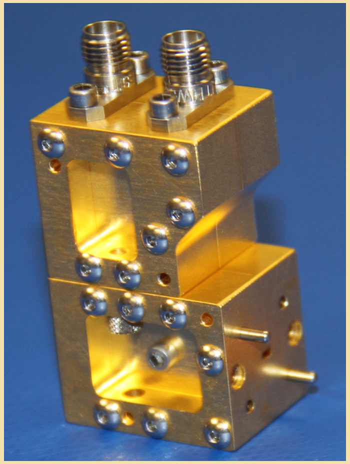
Operation from 18-29 GHz



Sensitivity better than 0.5 K (RMS)

Receiver front-end electronics developed by UMass-Amherst

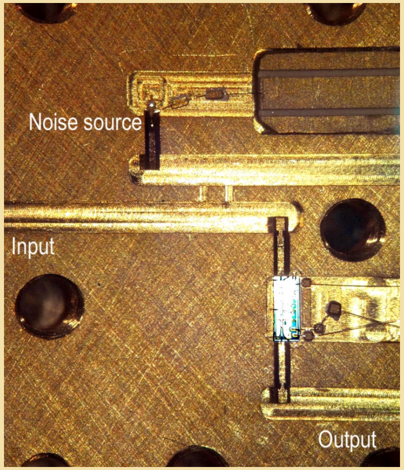
MMIC low-noise amplifiers and electronic calibration



Calibration accuracy better than 1 K (RMS)

Noise diode source provides periodic absolute calibration of radiometer

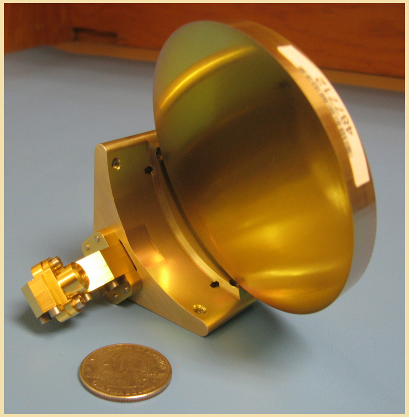
Highly stable; compact



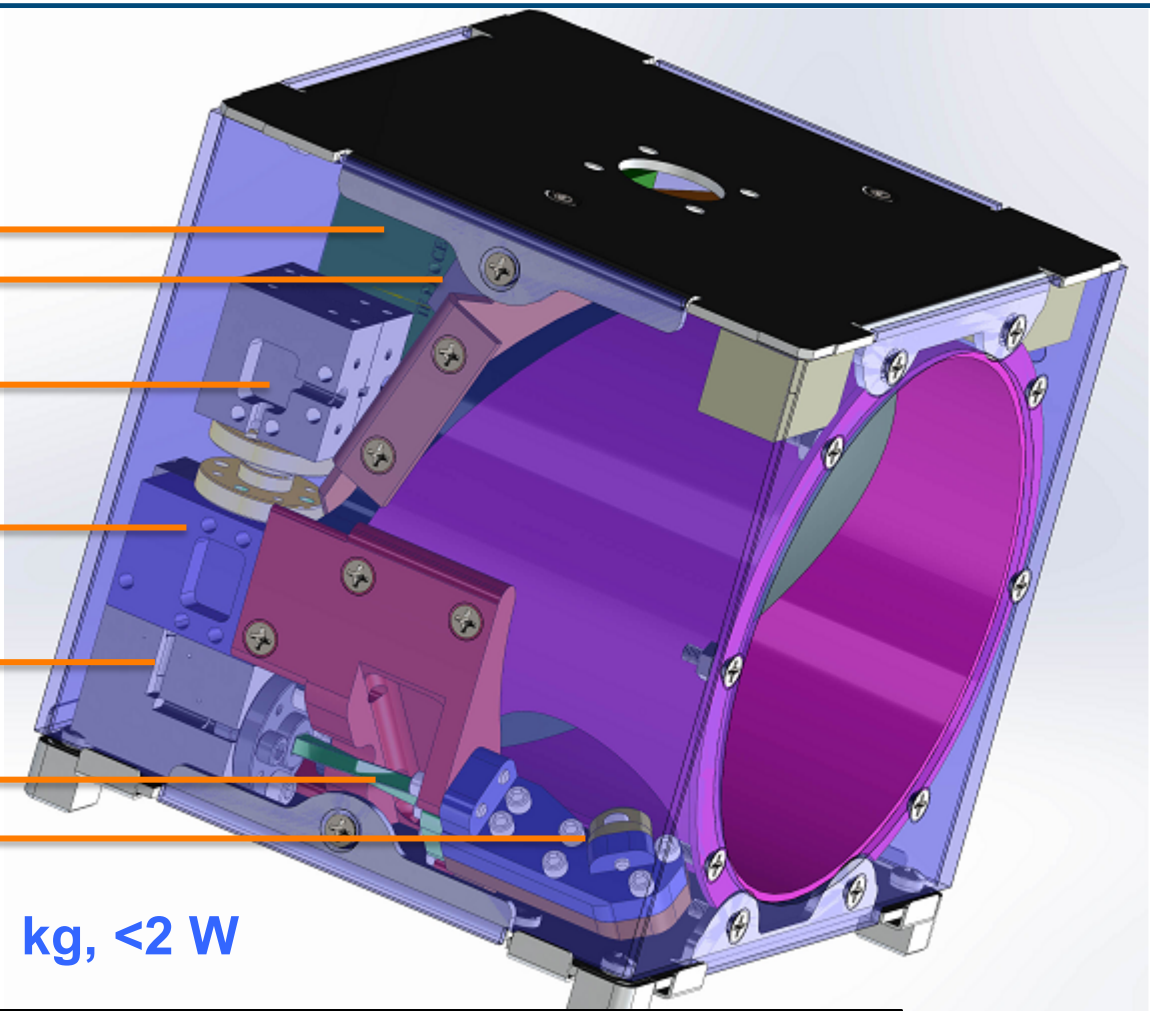
Aperture ~9 cm Beam efficiency > 95%

Offset parabolic reflector system with scalar feed

Lightweight, with 0.001" RMS surface tolerance



MicroMAS Payload (Side View) 118-GHz Spectrometer

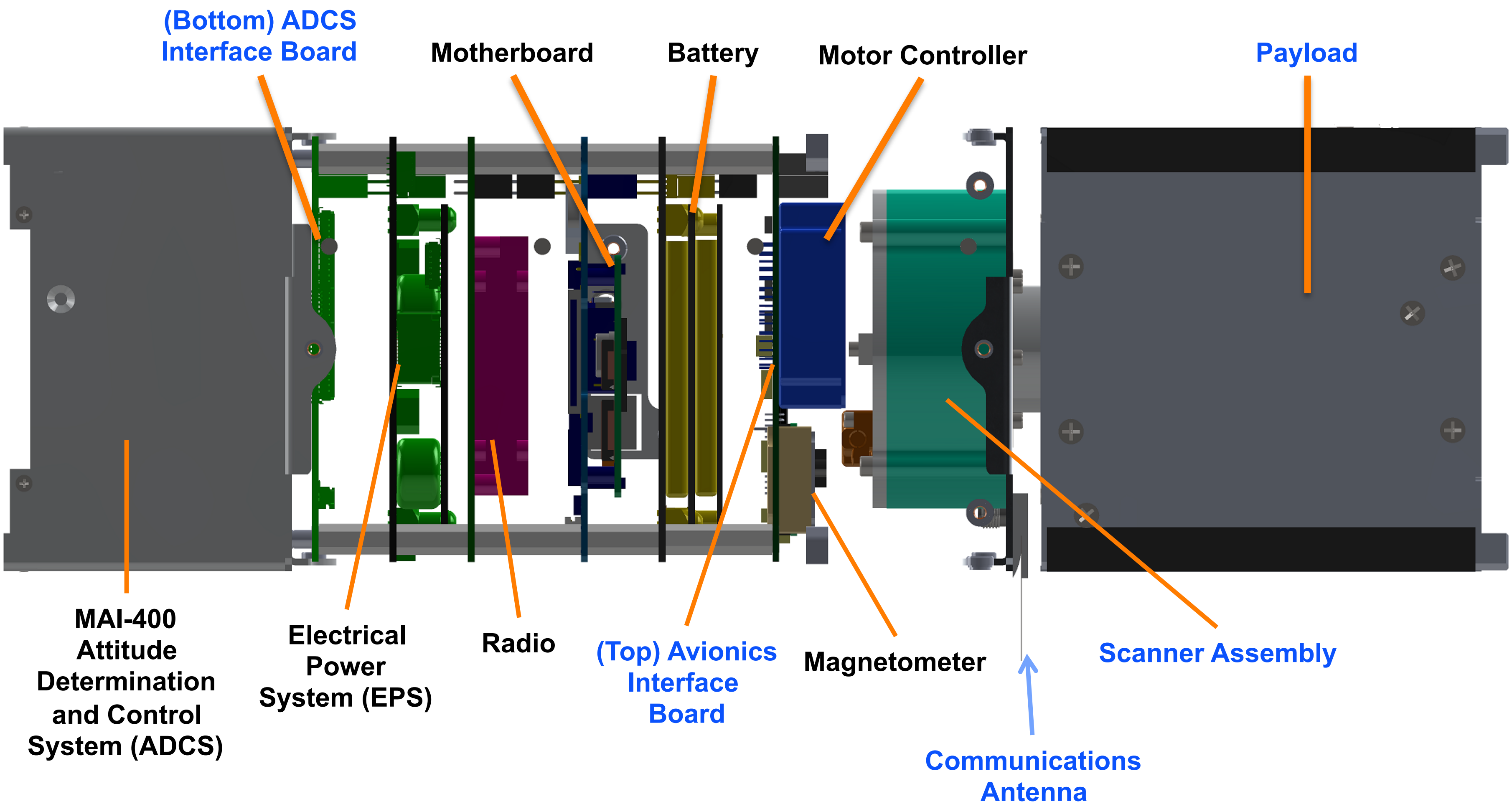


10x10x10 cm, <1 kg, <2 W

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

MicroMAS Bus Design

Custom vs. COTS Parts



Timely development of COTS parts was a major program challenge

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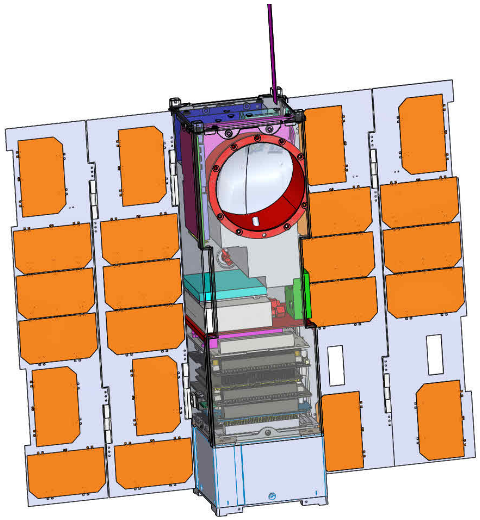
Microwave Radiometer Technology Acceleration (MiRaTA)

- **3U (10 cm x 10 cm x 34 cm) tri-band radiometer**
  - Temperature, water vapor, and cloud ice
  - Absolute calibration better than 1 K
- **Calibration proof of concept using limb measurements and GPS-RO**
  - Observe coincidental radiometric and GPS-RO atmospheric density information
  - Enabled by high-performance COTS GPS receivers with low size, weight, and power
- **Funded by NASA Earth Science Technology Office (ESTO)**



- 4 kg total mass
- 6 W avg power
- 5 kbps max data rate
- 0.5° pointing accuracy

GPS-RO + Radiometer

Progression of the tangent point for a setting (descending) occultation

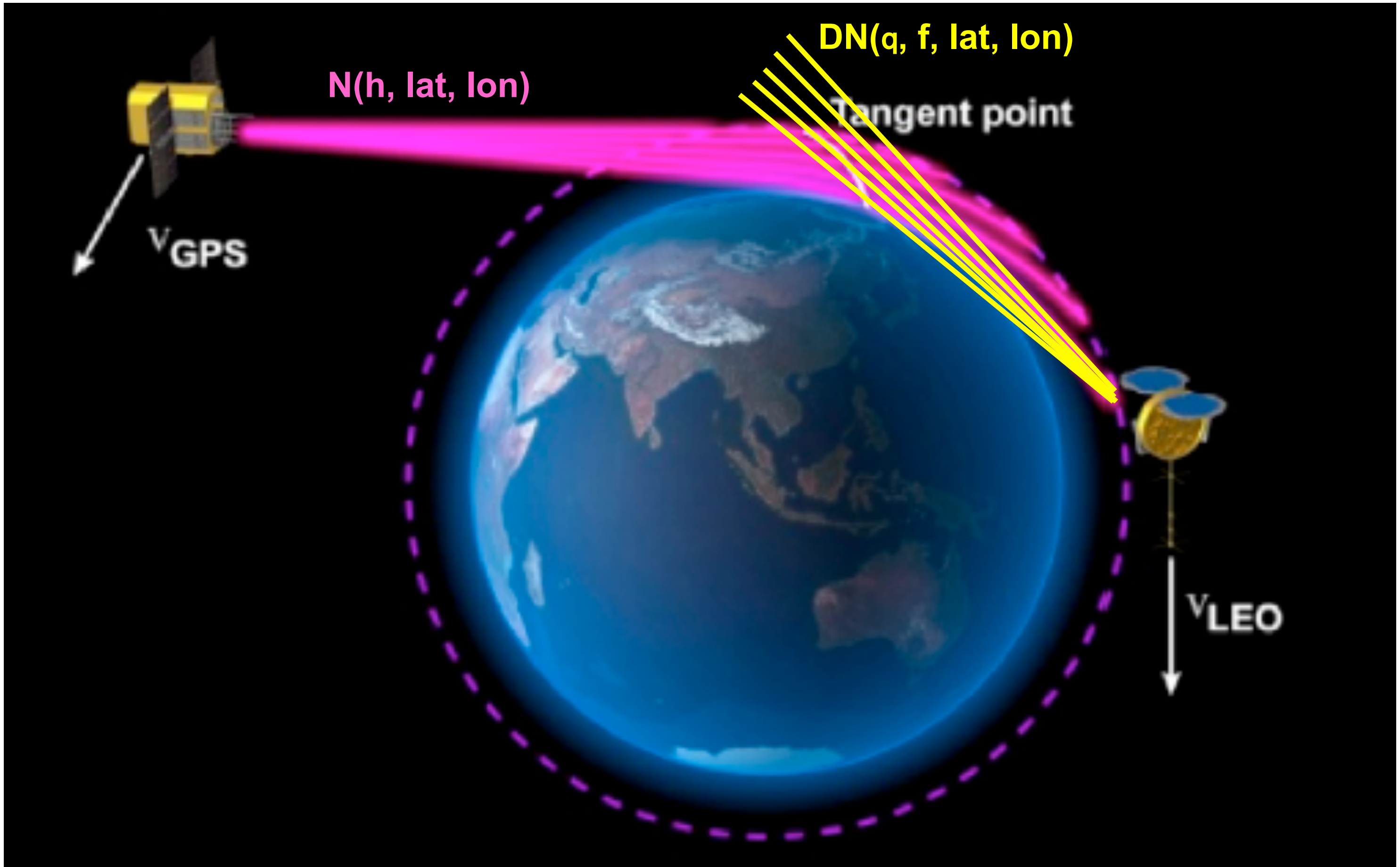
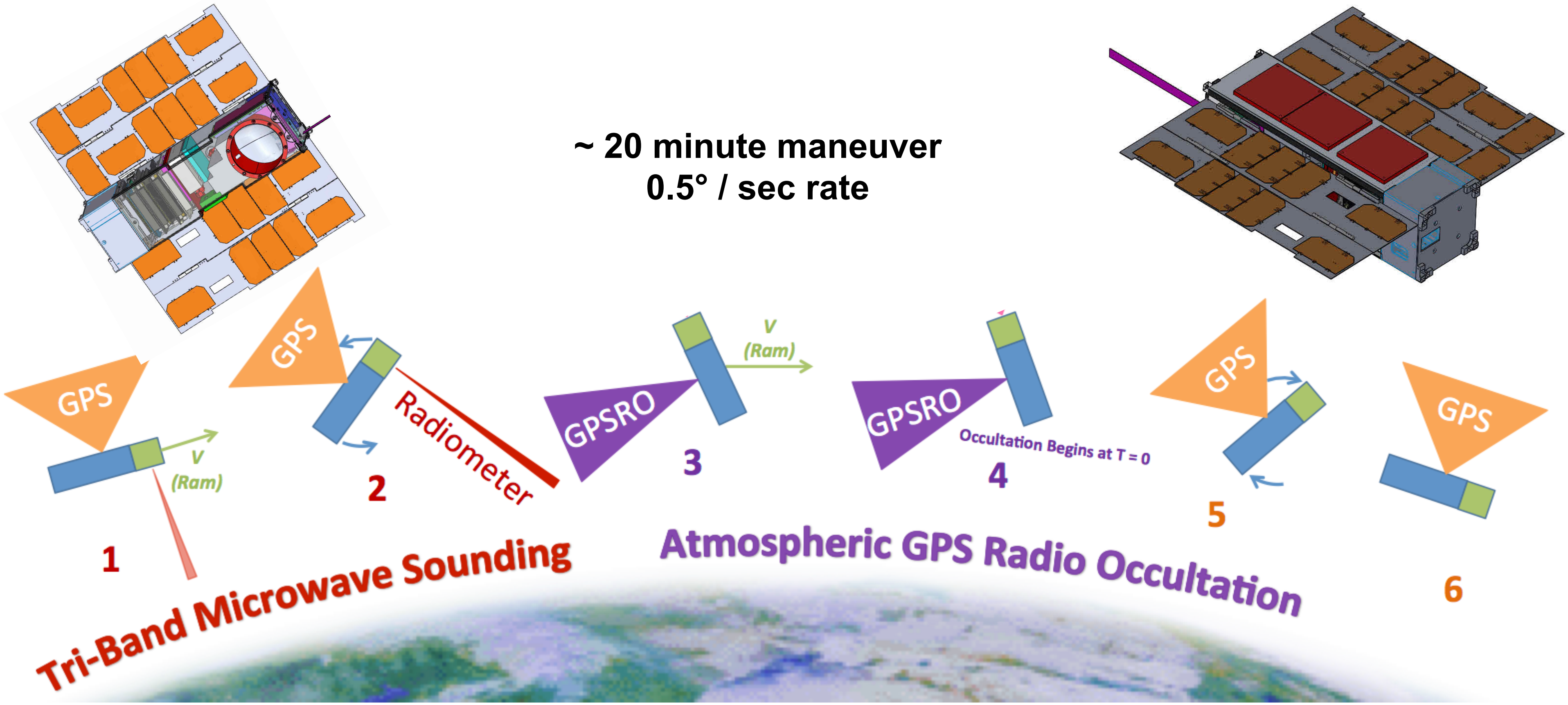


Image credit: Lidia Cucurull

MiRaTA Calibration Maneuver

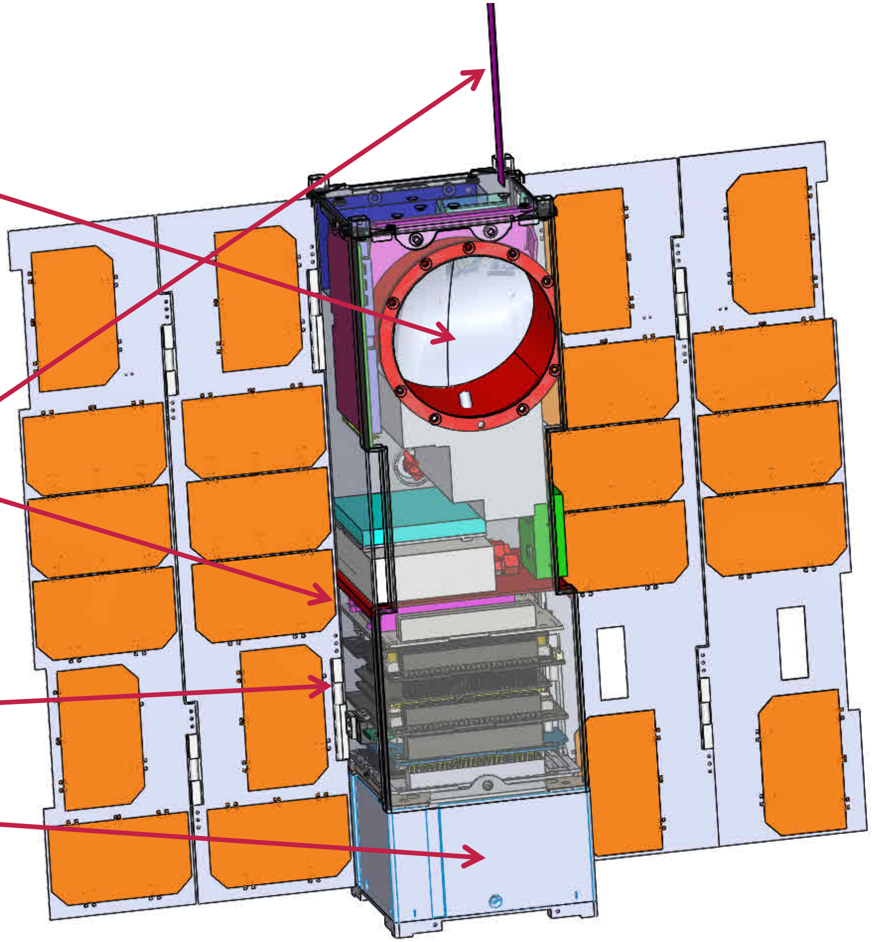
Nominal Sci Ops for Coupled Atmospheric GPSRO & Microwave Radiometry

~ 20 minute maneuver
0.5° / sec rate



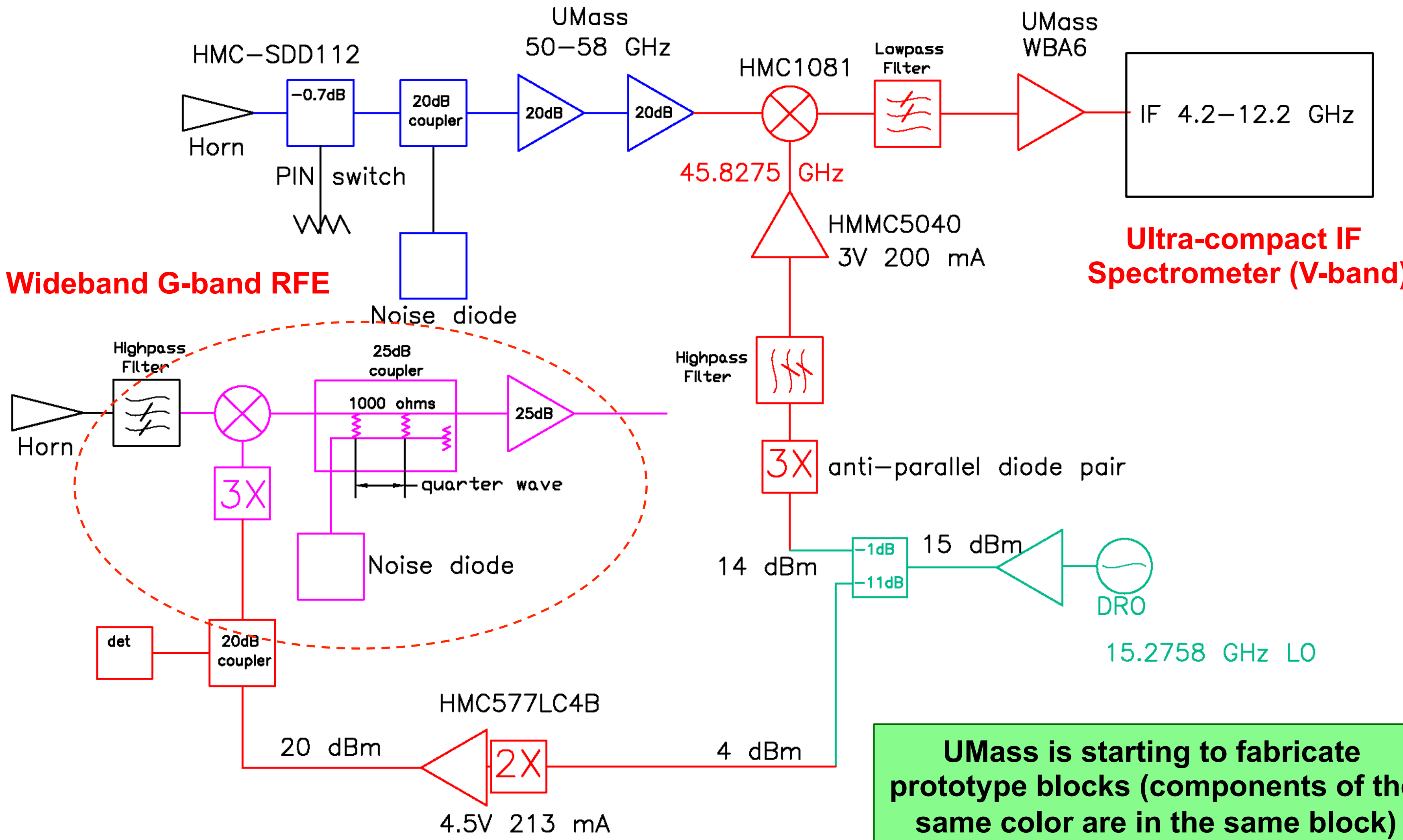
MiRaTA Space Vehicle

- **Payload**
  - Tri-band microwave radiometer
  - GPS radio occultation receiver with patch antenna array (on back)
- **Bus**
  - L-3 Cadet UHF Nanosatellite Radio with spring tape antenna*
  - Pumpkin PIC24F motherboard with Salvo RTOS*
  - Clyde Space EPS, battery, and double-sided deployed solar panels*
  - MAI-400 reaction wheels + Earth Horizon Sensors*
  - Custom interface boards



*** MicroMAS heritage**

Radiometer (UMass-Amherst & MIT LL)



Wideband G-band RFE

Ultra-compact IF Spectrometer (V-band)

UMass is starting to fabricate prototype blocks (components of the same color are in the same block)

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MiRaTA Status

- Procurement of major COTS components in progress
  - Flight and EM UHF radios delivered
    (L-3 Communications West Cadet Nanosatellite radio)
  - Power system (batteries, EPS, solar panels, harness) from Clyde Space
  - MAI-400 Reaction Wheel Assembly and Earth Horizon Sensors from Maryland Aerospace
  - Eyestar beacon radio (uses Globalstar constellation)
- Development of custom bus components and Payload
  - Tri-band Radiometer
  - CTAGS (The Aerospace Corp. GPS RO receiver and patch antenna array)
  - Avionics interface boards
- Preliminary Design Review Oct. 22-31, 2014
- Opportunity for a NASA ELaNA 600 km SSO 13:30 LTDN orbit
  - SSO orbit delivery in April 2016
  - NanoRacks ISS deployment also an option

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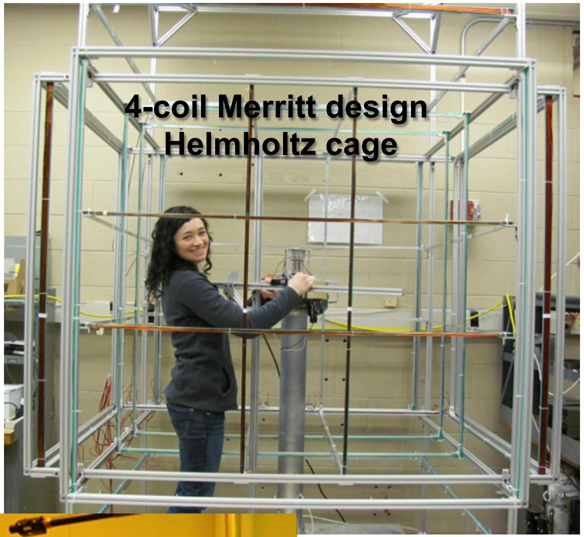
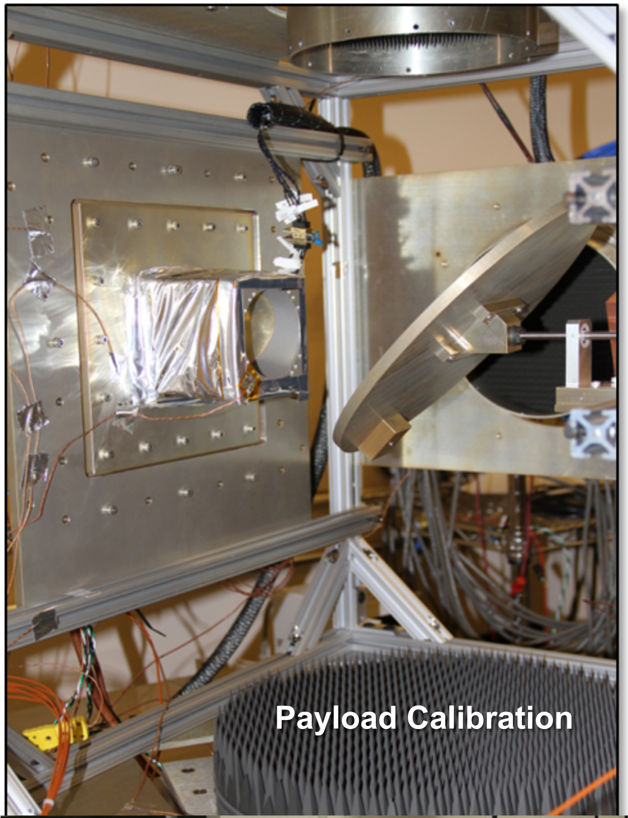
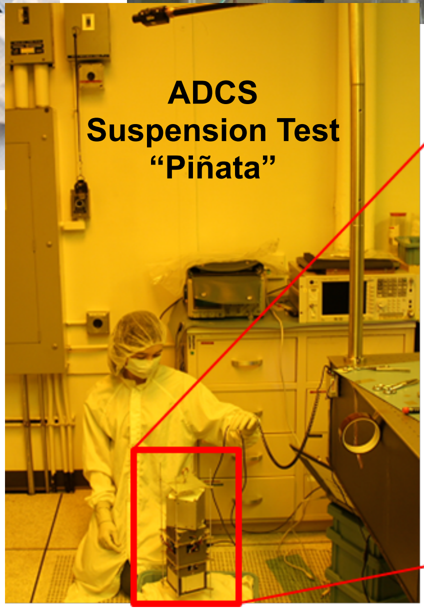
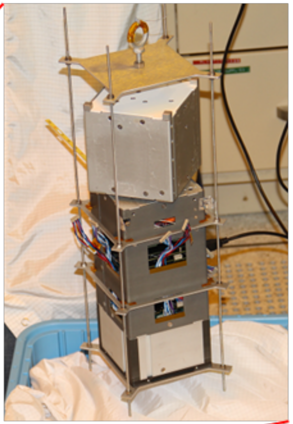
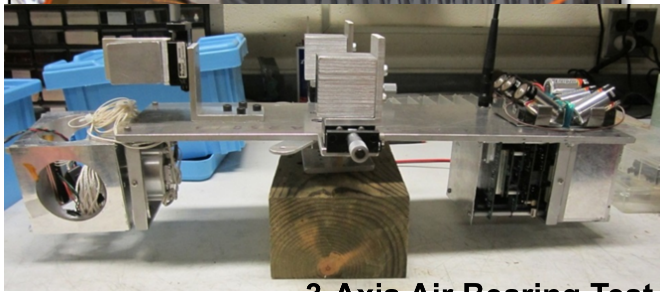
MiRaTA / MicroMAS Testing





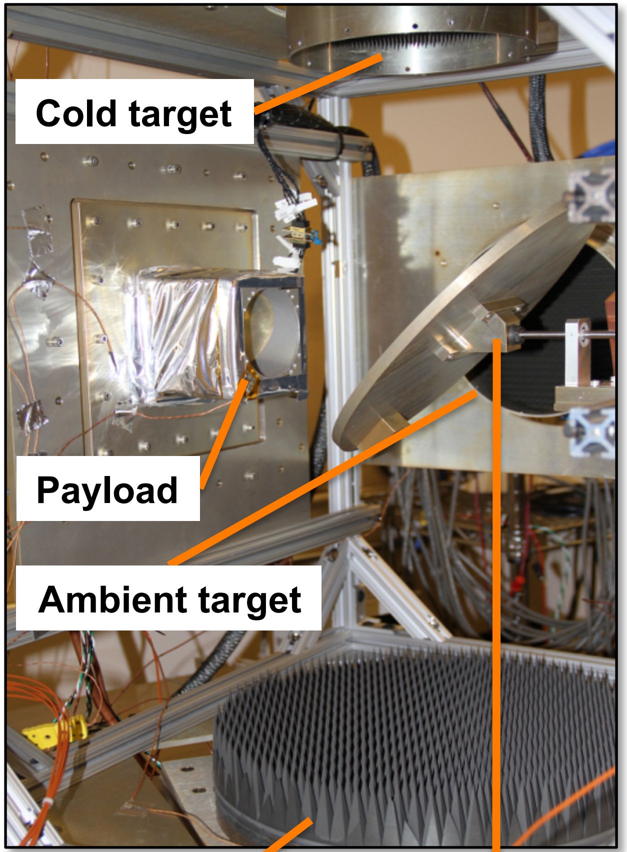


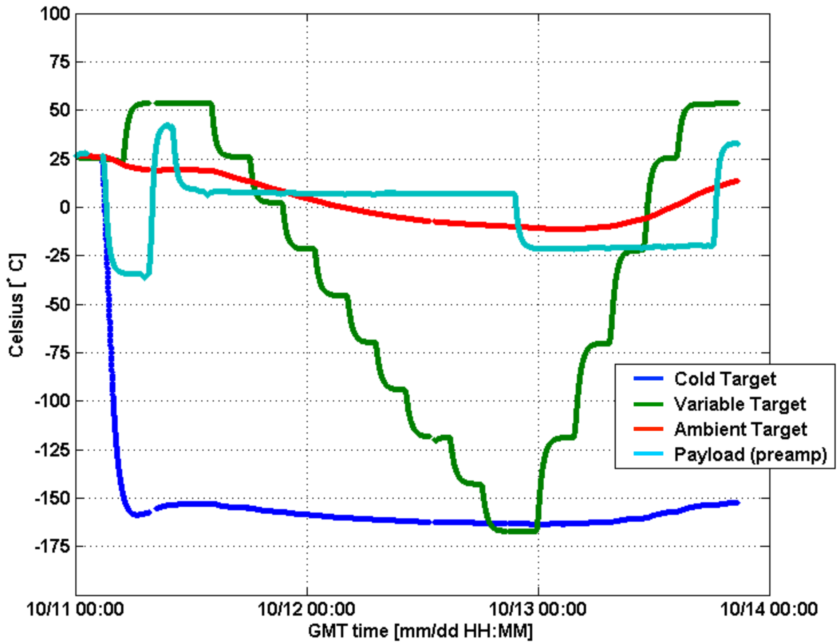




3-Axis Air Bearing Test

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

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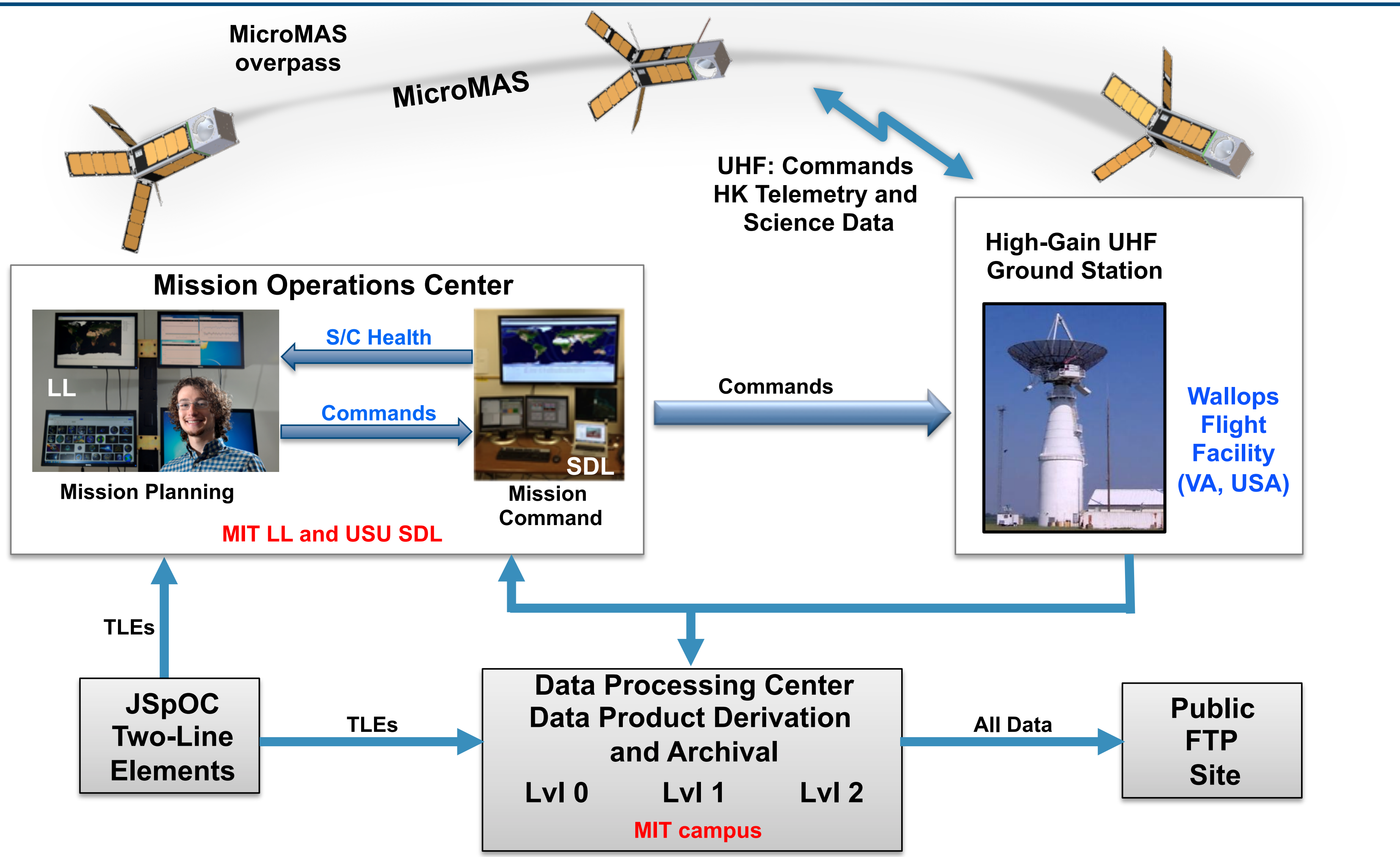
MiRaTA / MicroMAS Ground & Data Segment



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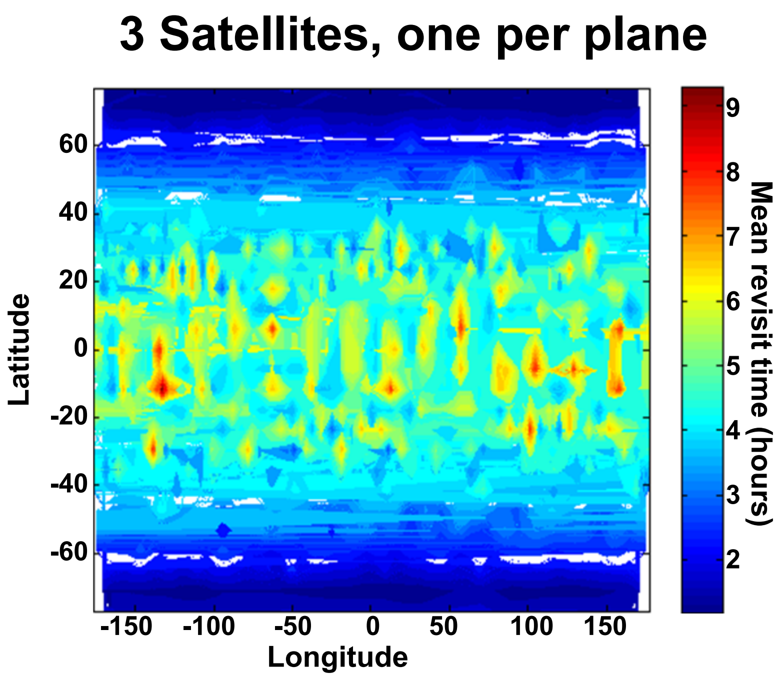
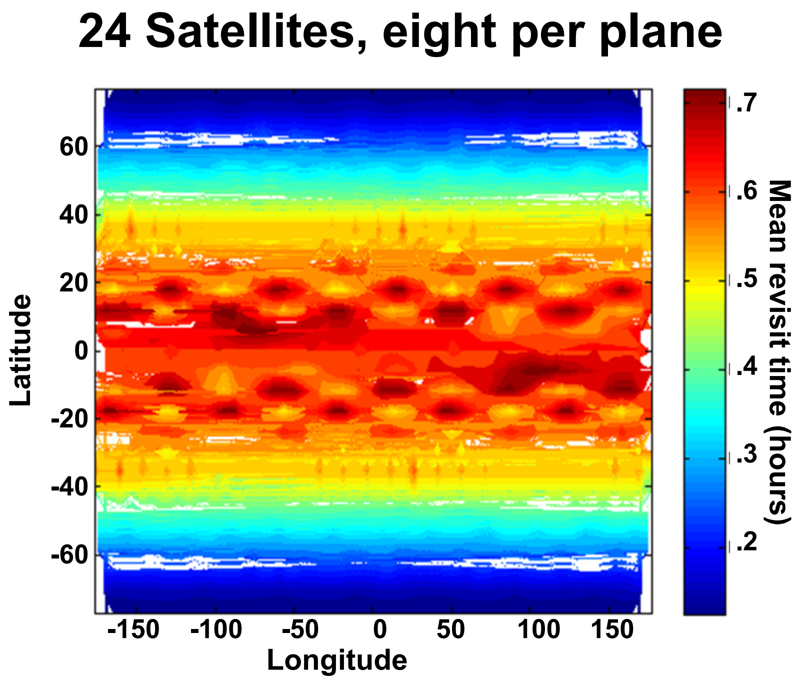
Summary and Path Forward

- Nanosatellite sounding constellations could provide unprecedented performance at relatively low cost and risk
- MicroMAS will demonstrate a core element of the constellation
- Ground testing has indicated excellent performance
  - 40 RPM scanning
  - 2W payload power consumption
- July 13, 2014 launch, with upcoming deployment from ISS via Nanoracks
- Microwave Radiometer Technology Acceleration (MiRaTA)
  - Next generation follow-on with multiple bands (temp. and water)
  - Demonstrate using tropospheric GPS RO for Radiometer calibration
  - Possible 600 km SSO LTDN 13:30 launch in 2016

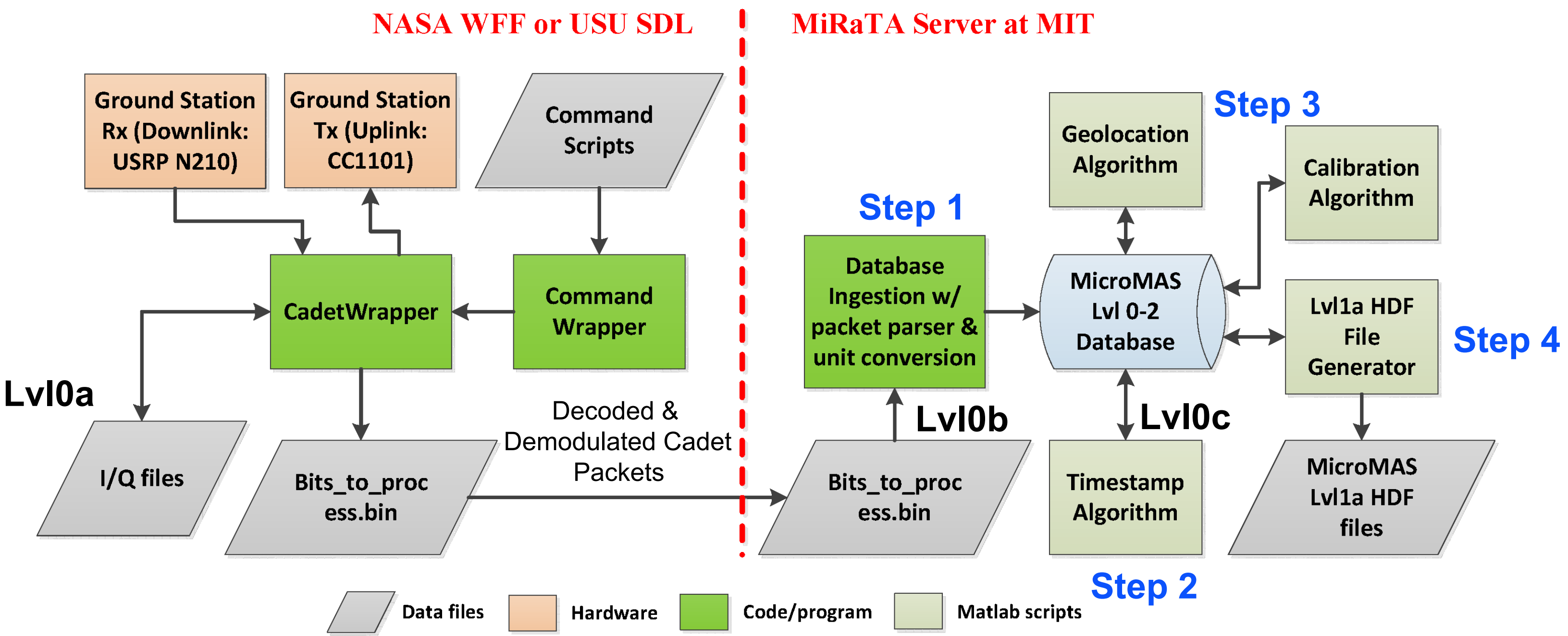
Backup

Architecture Studies Show Great Promise for Constellation Approaches





MicroMAS Operational Data Flowchart



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