The Microwave Radiometer Technology Acceleration CubeSat (MiRaTA)


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Outline

• Introduction and Motivation

• MiRaTA Goals
  – Microwave Radiometer
  – GPS Radio Occultation

• MiRaTA Status
  – MicroMAS lessons learned
  – MiRaTA status

• Next Steps

MicroMAS
Launched July 13, 2014
Orb-2 Antares/Cygnus
Deployed March 4, 2015
International Space Station
Courtesy NASA/NanoRacks
New Approach for Microwave Sounding

Advanced Technology Microwave Sounder (ATMS)

Suomi NPP Satellite
Launched Oct. 2011

Microsized Microwave Atmospheric Satellite (MicroMAS) Deployed Mar. 2015

NASA/GSFC

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

- Miniaturized microwave sensor aperture (10 cm)
- Broad footprints (~50 km), modest pointing requirements
- Relatively low data rate (kbps)
- Perfect fit for a CubeSat!

85 kg, 130 W instrument

2200 kg spacecraft
NPP: National Polar-orbiting Partnership
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Microwave Radiometer Technology Acceleration (MiRaTA)

- Two science instruments on a 3U CubeSat:
  - Tri-band microwave radiometer
    - Temperature (~60 GHz, V-band)
    - Water vapor (~183 GHz, G-band)
    - Cloud ice (~207 GHz, G-band)
    - Absolute calibration better than 1 K
  - GPS radio occultation receiver (GPSRO)
    - Called the Compact TEC Atmospheric GPSRO System (CTAGS)
    - Atmospheric temperature, pressure profiles
    - Ionospheric electron density and Total Electron Content (TEC)
- Goal: Demonstrate both payloads and use GPSRO to calibrate the radiometer by sounding overlapping volumes of atmosphere.
MiRaTA Space Vehicle

Acronym key:

- CTAGS, NovAtel OEM-628 + LNA
- PIM Payload Interface Module
- IFP Intermediate Frequency Processor
- EPS Electrical Power System
- LNA Low Noise Amplifier for GPSRO
- MAI-400 Maryland Aerospace Inc.
- ADCS Attitude Determination and Control
- EHS Earth Horizon Sensors

Radiometer Assembly

3U Double-Deployable Solar Panels
Overlapping GPSRO and Radiometer

Progression of the tangent point for an ingress (setting) occultation

Modification of image from Lidia Cucurull
MiRaTA Calibration Maneuver

Nominal Sci Ops for Coupled Atmospheric GPSRO & Microwave Radiometry

~ 20 minute maneuver
0.5° / sec rate
Radiometer and GPSRO Simulation

- Single set of GPS SV tracks over 24 hrs as rx’d by MiRaTA.
- Plot area is anti-ram FOV of MiRaTA GPS antenna array (85° x 30° full beamwidth)
- Post-LNA gain (dB) shown for L1. Goes to 5 dB at 81 km tangent height.
- Green bands show where radiometer field of view overlaps with GPSRO measurements.
Components of the same color are in the same block.

UMass Amherst has fabricated prototype blocks.
Science Payload Antennas

• CTAGS GPSRO Patch Array Antenna fabricated
  – Successful mechanical inspection completed
  – Electrical testing ongoing

• Radiometer Reflector Antenna Fabricated
  – Successful mechanical inspection completed
  – Electrical testing complete; data under analysis
Science Payload Modules

- Designs implemented; boards fabricated and testing of payload hardware is ongoing
- Engineering Design Units fabricated for critical payload components
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MicroMAS Debrief: Intro

- **MicroMAS 3U CubeSat**
  - 34 x 10 x 10 cm, 4.252 kg
  - 10 W average power
  - 118 GHz radiometer payload
    - 3D atmospheric temperature

- **MicroMAS deployed March 4, 2015**
  - Successful downlinks March 4, 5, 9
  - Radio transmitter issue
  - Unable to validate radiometer
  - Panels and antenna deployed
  - Power system and battery nominal
  - Obtained ADCS sensor data: IMU, magnetometer, EHS, sun sensors
  - Turned on MAI-400, reaction wheels
    - Wheels responded but unable to validate ADCS algorithms
MicroMAS Earth Horizon Sensors while tumbling

EHS A (Side) Measurements

Side-looking EHS is on the same side as panel YN

Room Temp ~1400 counts

EHS B (AntiRam) Measurements

Sun

Space
MicroMAS lessons learned

• Redundant radio needed
  – Implementing low-rate UHF radio on MiRaTA in addition to Cadet

• TLEs for ISS-deployed CubeSats not as good as predicted
  – Compare Riesing (SmallSat 2015) to Coffee et al., 2013

• Flight spares are a good idea

• Ensure all ADCS sensor parameters are tunable in case they are mis-labeled in code or have biases

• Power reset management is important tool

• Increased battery heating
MiRaTA Status

• Procurement of major COTS components nearly complete
  – Have Cadet radios, Pumpkin motherboard, Clyde Space EPS
  – Expecting Clyde Space solar panels, batteries, MAI-400 reaction wheel assembly and Earth Horizon sensors (MAI-400 electronics boards complete)

• Custom bus and payload components nearing completion
  – Have prototype avionics and interface boards
  – Have engineering unit payload modules
  – Flight model radiometer and GPSRO antennas fabricated

• Build of Mass Mockup and Ground Support Equipment for functional and environmental testing is underway

• Critical Design Review was June 1-3, 2015

• Still do not know what our launch/orbit will be (NASA CSLI)
  – Hoping for an SSO opportunity, but could work with ISS deployment
MiRaTA / MicroMAS Testing

TVAC

4-coil Merritt design Helmholtz cage

ADCS Suspension Test “Piñata”

Payload Spin Balance

Payload Calibration

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
MicroMAS Radiometer Performance
Accuracy and Precision

ATMS equivalent spot size; 250 K payload temperature
MiRaTA Ground & Data Segment

Mission Operations Center
- Mission Planning
- S/C Health
- Commands
- LL
- SDL
- MIT LL and USU SDL

Data Processing Center
- Data Product Derivation and Archival
- Lvl 0
- Lvl 1
- Lvl 2
- MIT campus

High-Gain UHF Ground Station
- Wallops Flight Facility (VA, USA)

Low-rate UHF, 400 MHz:
- TLM
High-rate UHF, 468 MHz:
- TLM, DATA
Ground UHF, 450 MHz:
- CMD

Commands

JSpOC Two-Line Elements
- TLEs

Public FTP Site
- All Data

MIT campus
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Summary and Next Steps

• There remains a need for near real-time, persistent, high-resolution and accurate global measurements of weather systems
  – Traditional aerospace approaches have budget and risk constraints that are at odd with improving temporal and spatial sampling
  – This directly compromises the science
  – Discoveries are often made using oversampled data
    • Reveals effects, behaviors, dependences that are not captured in models

• Tropical storms and hurricanes cause $5B of damage and property loss in the US alone each year
  – Estimated losses of 10,000 lives each year globally

• Nanosatellite sounding constellations will improve predictions and support more advanced and accurate warnings

• MiRaTA demonstrates performance of radiometer and CTAGS
  – MiRaTA EM functional testing Summer 2015
  – Flight SV Integration and Test activities Summer/Fall 2015
Acknowledgments

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Backup
Architecture Studies Show Great Promise for Constellation Approaches

3 Satellites, one per plane

24 Satellites, eight per plane
MicroMAS Operational Data Flowchart

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0a</td>
<td>Raw I/Q samples from USRP N210 containing L-3 Cadet packets</td>
</tr>
<tr>
<td>Level 0b</td>
<td>Decoded &amp; demodulated L-3 Cadet packets</td>
</tr>
<tr>
<td>Level 0c</td>
<td>Ingested MicroMAS packets with units converted and timestamped</td>
</tr>
<tr>
<td>Level 1a</td>
<td>Calibrated &amp; geolocated antenna temperatures at native resolution</td>
</tr>
</tbody>
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MiRaTA Space Vehicle

- **Payload**
  - Tri-band microwave radiometer
  - GPS radio occultation receiver with patch antenna array (on back)

- **Bus**
  - L-3 Cadet UHF radio* (3 Mbps)
  - Low-rate backup UHF radio (2.4 kbps)
  - 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

*flown on MicroMAS