The Microwave Accelerometer Technology Acceleration CubeSat (MiRaTA)


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MIT Lincoln Laboratory

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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)

- Visible/Infrared Imager Radiometer Suite (VIIRS)
- Cross-track Infrared Sounder (CrIS)
- Cloud and Earth Radiant Energy System (CERES)
- Advanced Technology Microwave Sounder (ATMS)
- Ozone Mapping and Profiler Suite (OMPS)

2100 kg

NPP: National Polar Partnership

Current Approaches Unsustainable

- Expensive
- Long development cycles
- Very high failure impact

Independent Assessment

NPP: National Polar Partnership
New Approach for Microwave Sounding

**Suomi NPP Satellite**
(Launched Oct. 2011)

**MicroMAS Satellite**
(Launched to ISS July 2014)

**Advanced Technology Microwave Sounder (ATMS)**

- 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

<table>
<thead>
<tr>
<th>Six or more channels</th>
<th>Sensitivity better than 0.5 K (RMS)</th>
<th>Calibration accuracy better than 1 K (RMS)</th>
<th>Aperture ~9 cm Beam efficiency &gt; 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultracompact spectrometer developed by Division 8</td>
<td>Receiver front-end electronics developed by UMass-Amherst</td>
<td>Noise diode source provides periodic absolute calibration of radiometer</td>
<td>Offset parabolic reflector system with scalar feed</td>
</tr>
<tr>
<td>Low-temperature co-fired ceramic filters</td>
<td>MMIC low-noise amplifiers and electronic calibration</td>
<td>Highly stable; compact</td>
<td>Lightweight, with 0.001” RMS surface tolerance</td>
</tr>
<tr>
<td>Operation from 18-29 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Image of Ultracompact spectrometer](image1)

![Image of Receiver front-end electronics](image2)

![Image of Noise diode source](image3)

![Image of Offset parabolic reflector system](image4)
MicroMAS Payload (Side View) 
118-GHz Spectrometer

IF Processor
Dielectric Resonator
Oscillator
Frequency Tripler
Mixer
Preamplifier/Noise-diode Module
Waveguide
Feed-horn

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
Timely development of COTS parts was a major program challenge.
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MicroMAS Launched July 13, 2014
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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

1. Tri-Band Microwave Sounding
2. Radiometer
3. GPSRO
4. GPSRO
5. GPS
6. GPS
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)

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
MiRaTA / MicroMAS Testing

- TVAC
- 4-coil Merritt design Helmholtz cage
- Payload Calibration
- Payload Spin Balance
- ADCS Suspension Test “Piñata”
- 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
MiRaTA / MicroMAS Ground & Data Segment

Mission Operations Center

MicroMAS overpass

UHF: Commands
HK Telemetry and
Science Data

High-Gain UHF
Ground Station

Wallops
Flight
Facility
(VA, USA)

JSpOC
Two-Line
Elements

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

Public
FTP
Site

MIT LL and USU SDL

S/C Health

Commands

Commands

TLEs

All Data

MIT LL and USU SDL
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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
Architecture Studies Show Great Promise for Constellation Approaches

3 Satellites, one per plane

24 Satellites, eight per plane
## MicroMAS Operational Data Flowchart

### Data Product Description

<table>
<thead>
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<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>
</table>