MicroMAS: Updates on the Global Environmental Monitoring Nanosatellite Mission


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MicroMAS SmallSat

WJB 7/17/2014

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)

- 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)

Current Approaches Unsustainable

- Expensive
- Long development cycles
- Very high failure impact

Independent Assessment

NPP: National Polar Partnership
Focus: Microwave Sounding

Suomi NPP Satellite (Launched Oct 2011)

Advanced Technology Microwave Sounder (ATMS)

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

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

**Perfect fit for a cubesat!**

MicroMAS Satellite (Launched Jul 2014)
- 4.2 kg, 10 W, 34 x 10 x 10 cm

Suomi NPP Satellite (Launched Oct 2011)
- Advanced Technology Microwave Sounder (ATMS)
- 100 kg, 100 W

2100 kg

NPP: National Polar Partnership

NASA/GSFC
Architecture Studies Show Great Promise for Constellation Approaches

3 Satellites, one per plane

24 Satellites, eight per plane

Latitude
Longitude

Mean revisit time (hours)

60 40 20 0 -20 -40 -60
-150 -100 -50 0 50 100 150

60 40 20 0 -20 -40 -60
-150 -100 -50 0 50 100 150

Mean revisit time (hours)

.7
.6
.5
.4
.3
.2

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DOME Constellation Concept

DOME = Distributed Observatory for Monitoring Earth (18 CubeSats)

DOME will provide 30-km mean horizontal resolution for sounding within hurricane eyes

Super Typhoon Haiyan (Nov 6, 2013) 90 GHz imaging (shown) and 118-GHz sounding penetrate the cloud tops

DOME will meet the PATH T(h) requirement

DOME will provide 15-minute median refresh rate at all longitudes and ± 40 latitude

VIS/IR observations are blind to storm structure
Constellation Improves Forecast

**Figure credit: Jun Li, University of Wisconsin**
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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

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

### Receiver Front-end Electronics
- Developed by UMass-Amherst
- MMIC low-noise amplifiers and electronic calibration

### Calibrator
- Noise diode source provides periodic absolute calibration of radiometer
- Highly stable; compact

### Antenna
- Offset parabolic reflector system with scalar feed
- Lightweight, with 0.001” RMS surface tolerance

### Spectrometer
- Ultracompact spectrometer
- Developed by Division 8
- Operation from 18-29 GHz
**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)**
Timely development of COTS parts was a major program challenge.
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
MicroMAS Assembly
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(Orbital/Cygnus ISS Resupply)
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

![Graphs showing temperature transients](image-url)
Accuracy Meets 1 K Requirement

Bias corrections applied to external calibration targets
Sensitivity (NEDT) @ 300 K Scene

Channel

NEDT (K)

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
• ~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 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)