Microwave Radiometers for Small Satellites

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Overview

- **Motivation**
- Microwave Radiometers
- MiRaTA
- MicroMAS
- TROPICS

Motivation: Predicting the Weather

Hurricane Ike, 2008

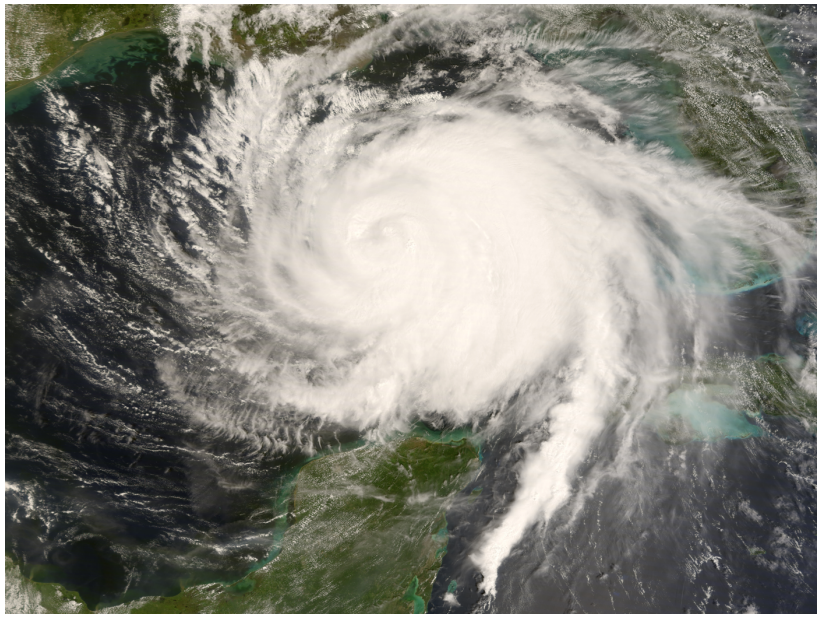


Image: NASA MODIS

Hurricane Ike damage near Galveston, TX

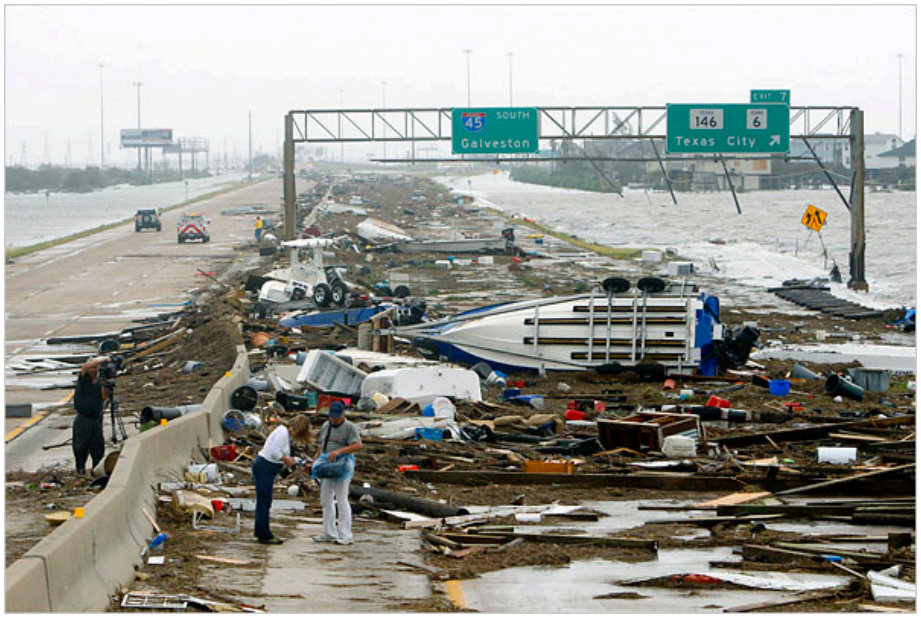
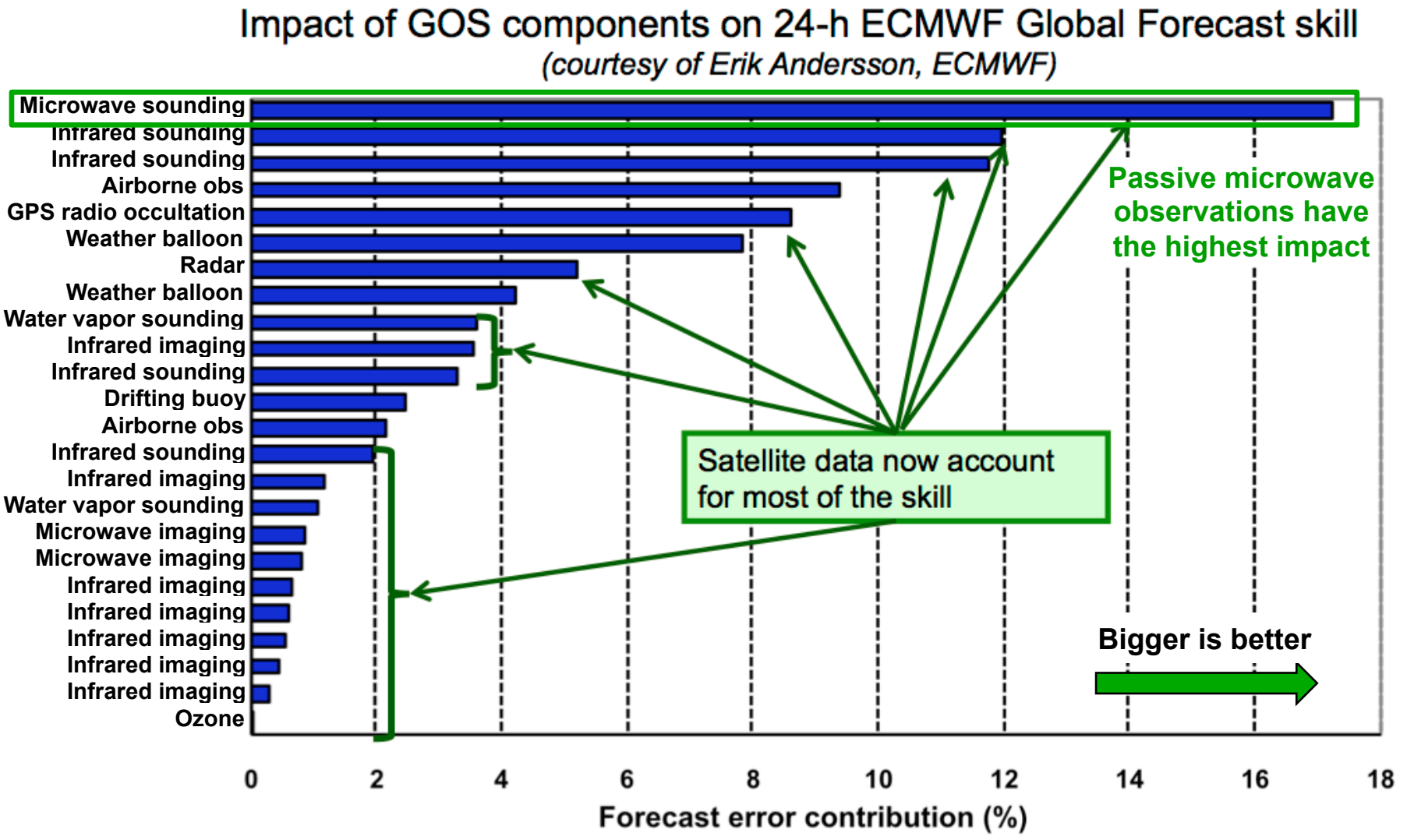


Image: NY Times

- **The US derives $32 B of value from weather forecasts annually[1]**
- **Satellites that observe Earth drive the forecasts**
- **Need to observe the entire Earth, all the time, with quick availability, of temperature, water vapor, and cloud ice**

[1]University Center for Atmospheric Research

Satellites Provide the Most Forecast Skill



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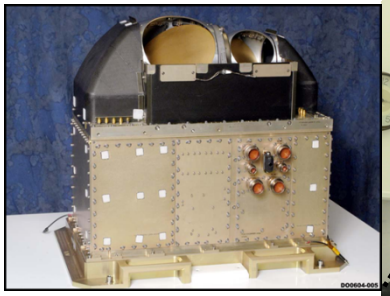
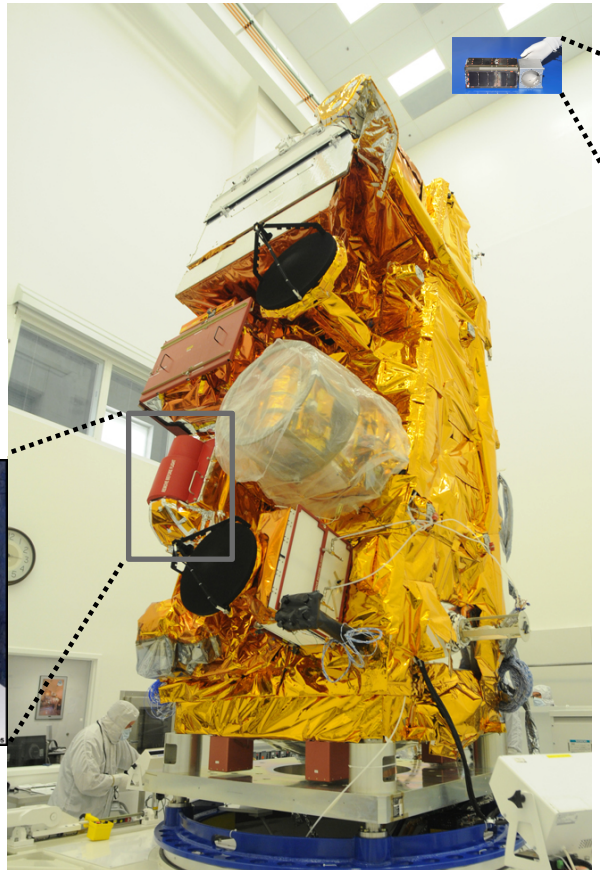
New Approach for Microwave Sounding

Advanced Technology Microwave Sounder (ATMS)



85 kg, 130 W

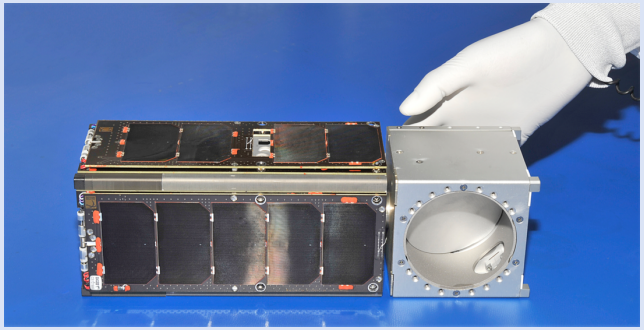


2100 kg **NASA/GSFC**

Suomi NPP Satellite (Launched Oct. 2011)

NPP: National Polar-orbiting Partnership

MicroMAS-1 CubeSat



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

- **Map ~50 km footprints**
- **Small data stream: 16kbps**
- **Radiometer:**
  - 9 Channels
  - 118 GHz Band (Temperature Measurement)
- **Scan rate: 40 rpm**

Roadmap to a CubeSat Constellation

MicroMAS-1

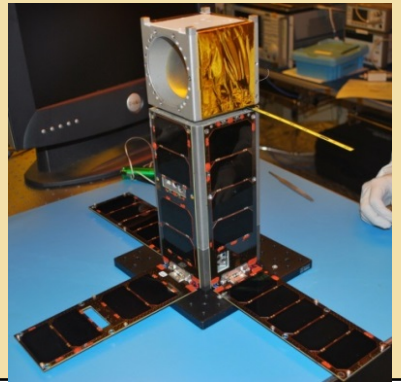
Scanning 3U CubeSat

Intended to measure 3D temperature

Launched in July 2014

ISS released it March 2015

Three successful contacts before radio failed

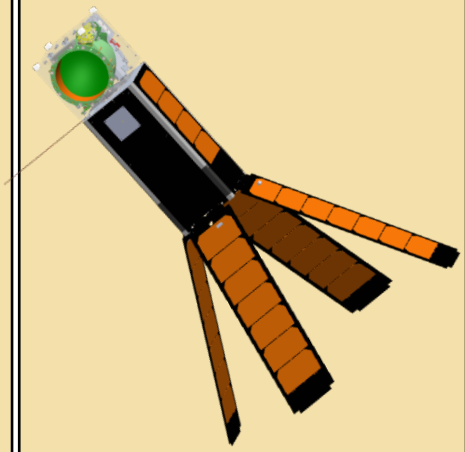


MicroMAS-2

Scanning 3U CubeSat

To measure temperature, water vapor, and cloud ice

Two launches planned in 2017



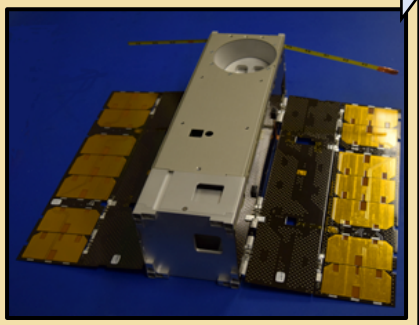
MiRaTA

Pitch-up 3U CubeSat

To measure temperature, water vapor, and cloud ice

GPS radio occultation to enable <1 K calibration

Sept. 2017 launch with JPSS-1



TROPICS

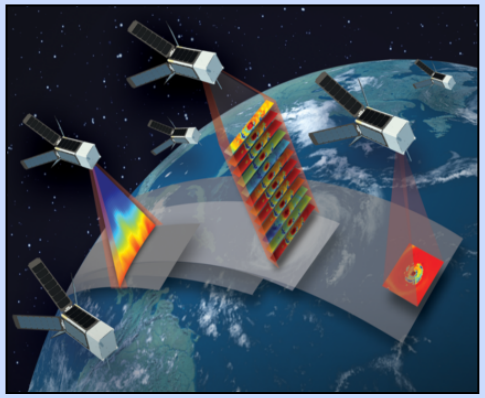
Selected for EVI-3

6-8 CubeSats (3U) in three orbital planes

To measure temperature, water vapor, and cloud ice

30-minute revisit

2020 launch



MiRaTA
~60 GHz (temperature, V-band)
~183 GHz (water vapor, G-band)
~206 GHz (cloud ice, G-band)

NASA ESTO

NASA EVI-3
Earth System Science Pathfinder
Science Mission Directorate

Overview

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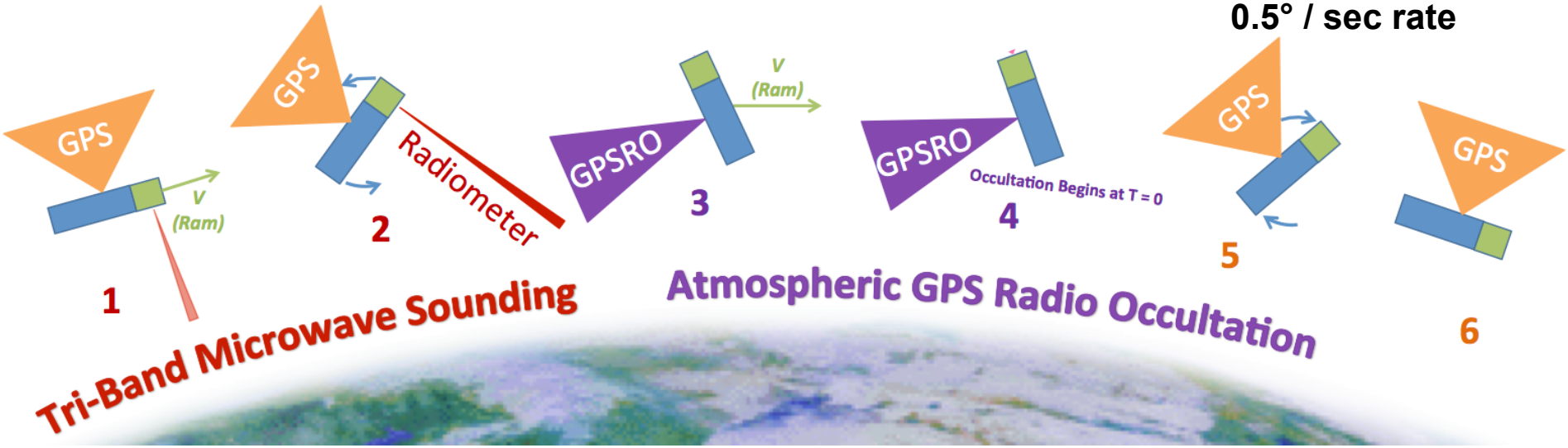
MiRaTA Mission

MiRaTA: Microwave Radiometer Technology Acceleration

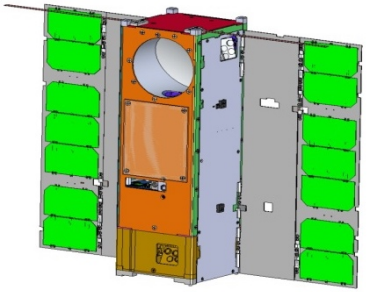
- **Payloads:**
  - Microwave Radiometer:
    - 10 Channels
    - 60 GHz – Temperature
    - 183 GHz – Humidity
    - 206 GHz – Cloud Ice
  - CTAGS: Compact Total Electron Content Atmospheric GPSRO System
    - Provided by Aerospace Corp.
- **Advance TRL from 5 to 7 for:**
  - IF Spectrometer (Radiometer Payload)
  - G-band Mixer (Radiometer Payload)
  - GPSRO Receiver (CTAGS Payload)
- **Microwave radiometer calibration using GPS radio occultation**

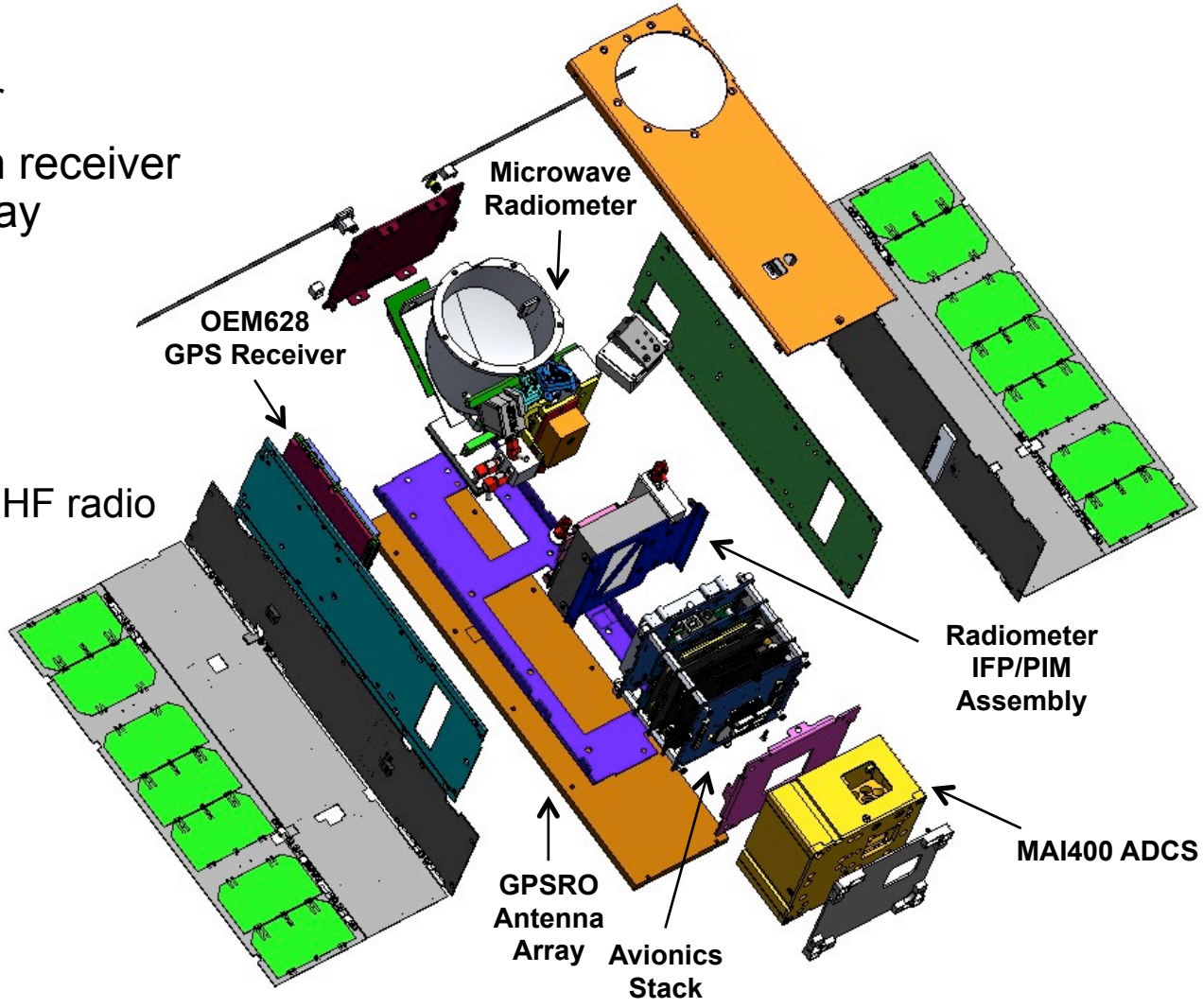
~ 10 minute maneuver
0.5° / sec rate



MiRaTA Space Vehicle

- **Payloads**
  - Microwave Radiometer
  - GPS Radio Occultation receiver and Patch Antenna array (GPSRO or CTAGS)
- **Bus**
  - Cadet UHF Radio
  - Avionics Stack
    - With low data-rate UHF radio and antenna
  - Attitude Determination and Control System

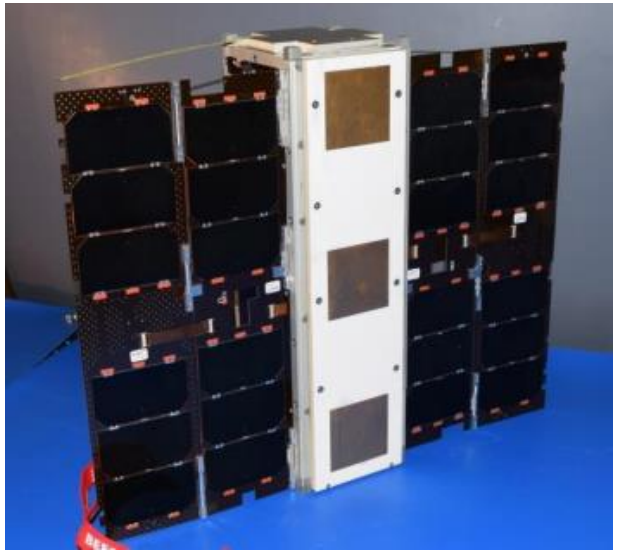




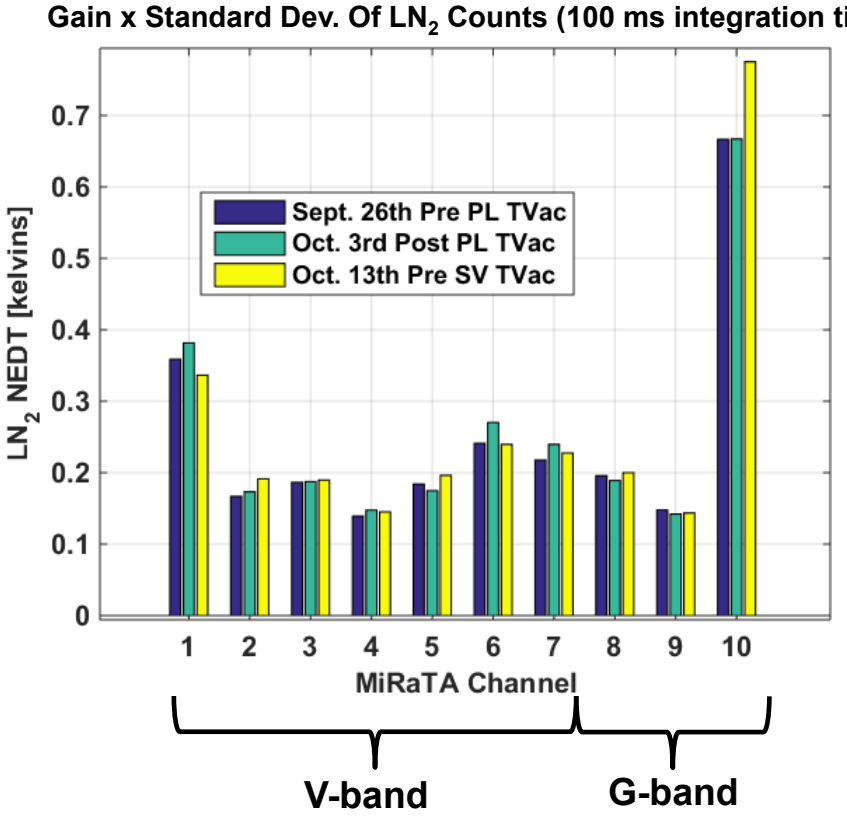
MiRaTA Status

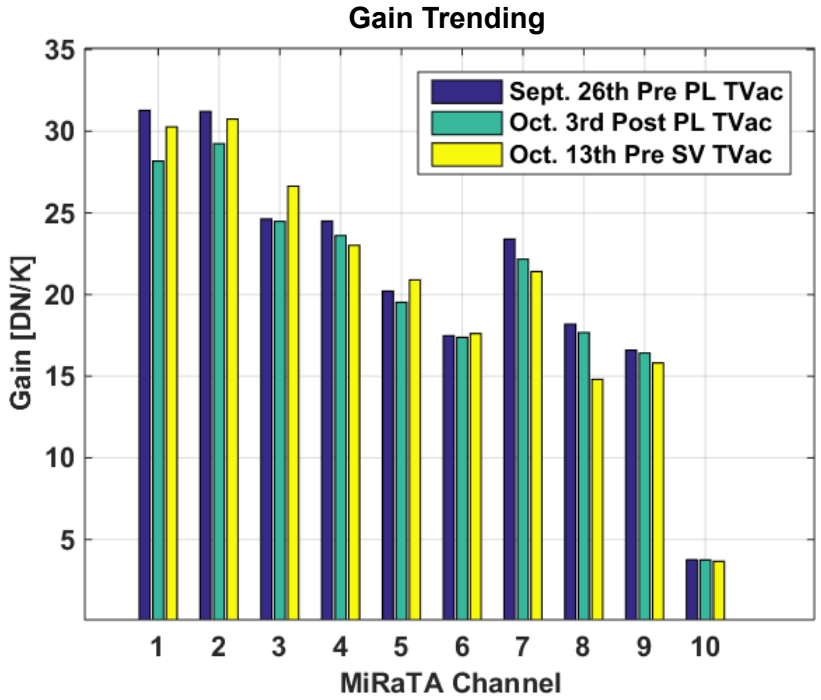
- **Integration and environmental testing complete**
- **Calibration data obtained**
- **Ongoing work**
  - Low-rate UHF radio ground station being built at MIT
  - GSE setup and test at NASA Wallops in conjunction with Utah State SDL
- **Launching with JPSS-1 in Sept. 2017**

Fully Integrated Space Vehicle prior to final solar panel tie down



MiRaTA Radiometer Calibration





Overall, system meets TRL advancement requirements.

Preliminary results show values well within range for:

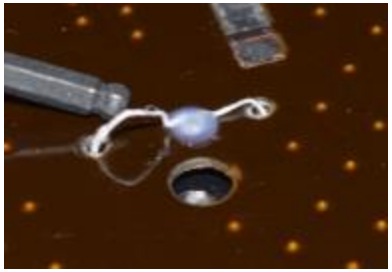
- Gain (accuracy)
- NEdT (precision)

Further processing will address:

- Noise Diode radiance slightly coupled to scene radiance.
- EMI between V and G bands.
- Characterize V-Band matched load radiance.

Space Vehicle Integration Issues and Lessons Learned

- **Solar panel tie-down break during vibe**
  - Movement during vibration testing was cut from rubbing on a corner
  - Additional staking was added to the knot to limit its movement

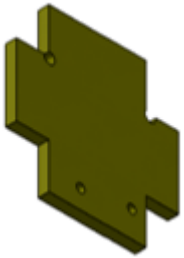


Broken tie-down

Intact tie-down after vibration testing

- **CG Location out of spec by 4.6mm**
  - Ballast was added to move it within acceptable bounds

- **Two radiometer channels were unresponsive**
  - Work on these channels was preventing bus and payload integration
  - 10 channels were responsive
  - Due to schedule pressures and the other working channels, this was deemed acceptable for the mission



CAD model of ballast plate

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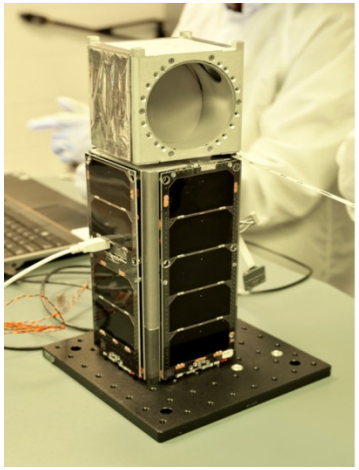
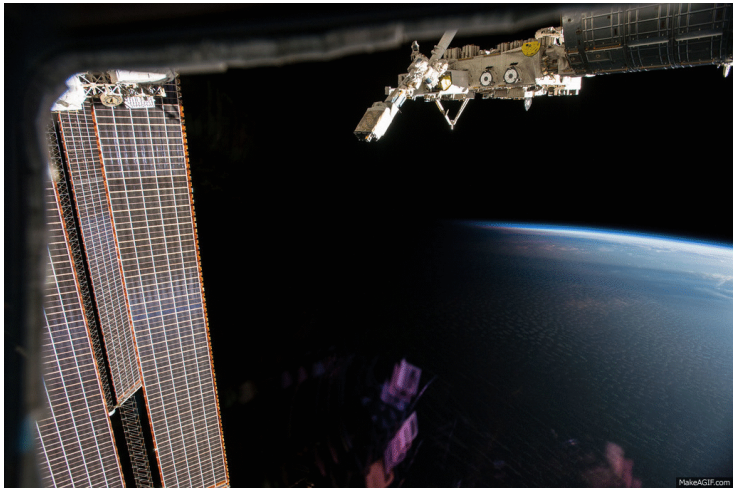
MicroMAS Overview

MicroMAS: Micro-sized Microwave Atmospheric Satellite

- **MicroMAS-1:**
  - 3U dual-spinner CubeSat
  - High resolution cross track spectrometer
  - 9 Channels at the 118 GHz Band
- **MicroMAS-2 is a follow-up mission to MicroMAS-1**
  - 3U dual-spinner CubeSat
  - High resolution cross track spectrometer
  - 10 Channels, 4 bands
    - 89 GHz – water vapor
    - 207 GHz – water vapor
    - 118 GHz – temperature, pressure, precipitation
    - 183 GHz – humidity and precipitation
  - Beam width of 3°
  - Swath of 2500 km
  - Nadir resolution of 20 km



MicroMAS-1 in stowed configuration

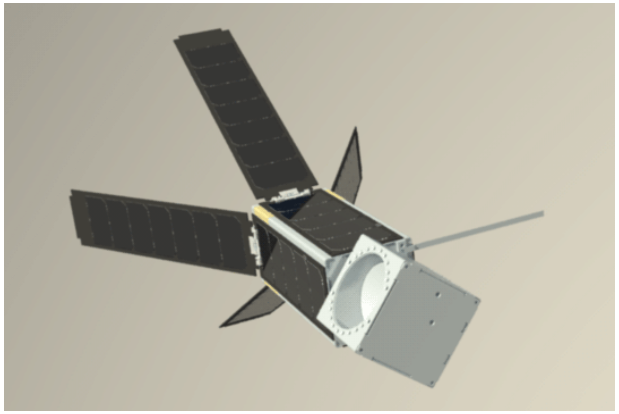


MicroMAS-1 being deployed from the ISS

MicroMAS-2 Status

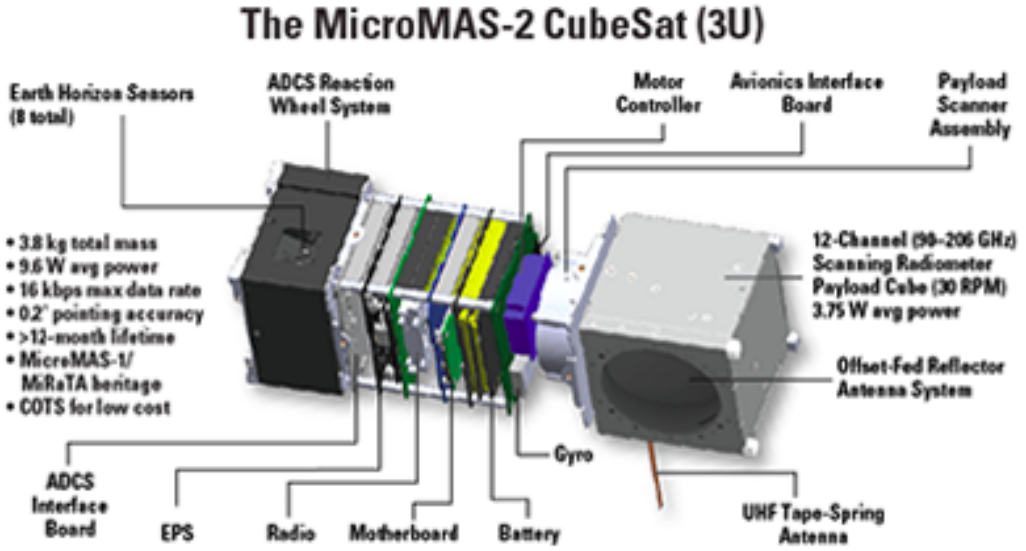
MM-2a:

- In SV TVac today through June 20
- Vibe, June 30
- Data package due: mid July 2017
- Delivery: early August 2017
- Launch: early Oct 2017, PSLV-7



MM-2b:

- Integration and test in progress
- Delivery: Oct. 2017 (TBC)
- Launch: Dec. 2017 (TBC)



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TROPICS Overview

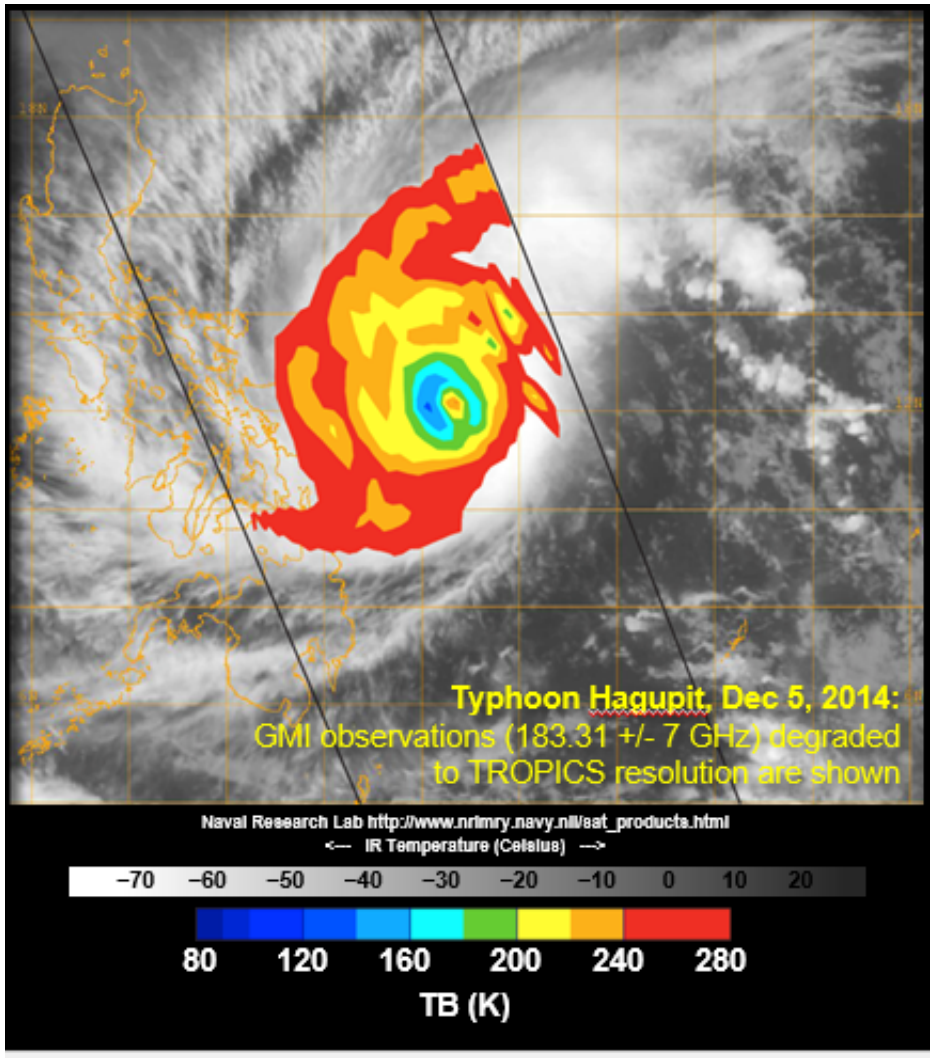
Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS)

- Provides observations of precipitation, temperature, and humidity with a high-revisit rate in Earth's tropical regions
- Constellation involving at least 6 CubeSats in 3 orbital planes
- Commercial 3U bus
- MIT LL radiometer payload
- ~30 minute median revisit rates
  - (with 12 CubeSats; update once config. set)
- Observations will improve knowledge and forecasting of high-impact tropical cyclones

https://tropics.ll.mit.edu/CMS/tropics/tropics-mission-implementation

TROPICS Status

- **Bus vendor selection in progress**
- **Radiometer payload improvements from MicroMAS-2**
  - Manufacturability
  - Ease of calibration
- **2020 launch expected, likely on a dedicated small satellite launcher**



Conclusion

- **MiRaTA will demonstrate new radiometer technology and calibration approaches on single CubeSat**
- **MicroMAS-2 adds bands to MicroMAS-1 and demonstrates scanner**
- **TROPICS leverages these advances with multiple CubeSats, working towards an operational constellation with lower revisit times**

JPSS ATMS and MicroMAS-2

	ATMS JPSS-1	MicroMAS-2 3U CubeSat
Scan Range	Cross Track: 2.2° – 6.3° Along Track: 1.1° – 5.2° Swath: 2600 km	FOV: 5° Scan Angle: 115° Swath: 2590 km
Nadir Resolution	15.8 - 74.8km	20 km
Total Channels	22	10
Spectral Bands	23.8 GHz, 31.4 GHz, 50-55 GHz (7 channels), 57.26 GHz (6 channels), 88 GHz, 165 GHz, 183 GHz (5 channels)	89 GHz, 118 GHz (5 channels), 183 GHz (3 channels), 206 GHz
NEdT @300 K	0.5-3.0 K	0.1 - 0.6 K
Mass	85 kg	3.8 kg
Power	130 W	9.1 W
Max Data Rate	32 kbps	16 kbps