GeoOptics

Changing the Paradigm
--
From "Battle Stars" to Nanosats

AMS Washington Forum
Washington DC
April 24-26, 2018

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CEO, GeoOptics, Inc

Agenda

- Current LEO "Battle Star" System
  - JPSS
- Future LEO Nanosat System
  - Microwave Atmospheric Satellite (MicroMAS)
  - Microwave Radiometer Technology Acceleration (MiRaTA)
  - Compact Infrared Radiometer in Space (CIRiS)
  - CubeSat Infrared Atmospheric Sounder (CIRAS)
  - Microwave Atmospheric Sounder On CubeSat (MASC)
  - Radar Precipitation Profiler (RainCube)
  - Snow and Water Imaging Spectrometer (SWIS)
  - Hyperspectral Imaging (GOMX-4B)
  - Radio Occultation (CICERO)
- Transition Plan*

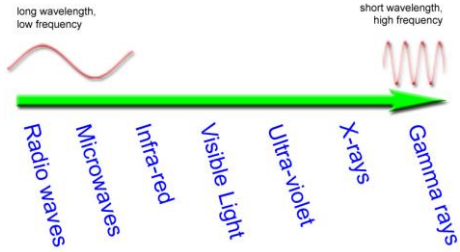
*TBD

Electromagnetic Spectrum*

Extreme ultraviolet	EUV		3 PHz	100 nm	12.4 eV	
ultraviolet	NUV	Near ultraviolet		300 THz	1 µm	1.24 eV
Visible	NIR	Near infrared		30 THz	10 µm	124 meV
Infrared	MIR	Mid infrared		3 THz	100 µm	12.4 meV
	FIR	Far infrared		300 GHz	1 mm	1.24 meV
Micro-waves	EHF	Extremely high frequency		30 GHz	1 cm	124 µeV
and	SHF	Super high frequency		3 GHz	1 dm	12.4 µeV
radio waves	UHF	Ultra high frequency				

*Thomas Pagano, JPL, AIRS Program Update Oct 13, 2015

Electromagnetic Spectrum*



* http://www.darvill.clara.net/emag/index.htm

JPSS

- Visible Infrared Imaging Radiometer Suite (VIIRS)
  Collects **visible** and **infrared** imagery and global observations of land, atmosphere, cryosphere and oceans.
- Advanced Technology Microwave Sounder (ATMS)
  Collects **microwave** radiation from the Earth's atmosphere and surface day and night, even through clouds.
- Cross-track Infrared Sounder (CrIS)
  Collects **infrared** sounding (vertical profile) data

Weather Models

- Clouds and the Earth's Radiant Energy System (CERES)
  Measures reflected sunlight and thermal radiation emitted by the Earth.
  0.3 to 5 µm 8 to 12 µm 0.3 to >50 µm **ultraviolet, visible,** and **infrared**

Climate Monitoring

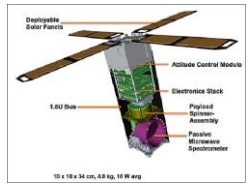
- Ozone Mapping and Profiler Suite (OMPS)
  Three spectrometers: **ultraviolet** downward-looking nadir, nadir, and limb profilers

Ozone Monitoring

* http://www.jpss.noaa.gov/instruments.html

Microwave Radiometer*

Microsized Microwave Atmospheric Satellite (MicroMAS)



Miniaturized dual-spinning antenna

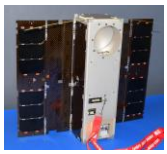
- low-cost, low-power, highly miniaturized 3U CubeSat
- High-resolution, fast imaging of Earth's atmosphere
- Miniaturized dual-spinning antenna
- Passive microwave spectrometer
  - 9 channels near 118.75-GHz oxygen absorption line.
- MIT Lincoln Laboratory, Massachusetts Institute of Technology

*https://directory.eoportal.org/web/eoportal/satellite-missions/m/micromas-1#mission-status

Microwave Radiometer*

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
  - CTAGS (Aerospace Corp. GPS RO receiver and patch antenna array)
- 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

UMass-Amherst & MIT LL

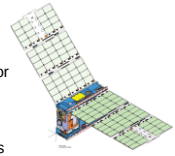
* https://esto.nasa.gov/forum/estf2014/presentations/B2P3_Cahoy.pdf

Infrared Imaging Radiometer*

Compact Infrared Radiometer in Space (CIRiS)

- Radiometric thermal infrared (~ 7.5 um to 12.7um) imaging
- 6U CubeSat spacecraft
- Pushbroom imaging in three bands from Low Earth Orbit

- Measure optical and physical properties of clouds, thermodynamic phase
- Measure land & sea surface temperatures for
- land management and climate studies
- Measure evapotranspiration to evaluate drought impact
- Determine ground water flow on large scales
- Measure earth's radiation budget/validate climate models



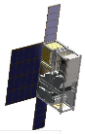
Ball Aerospace

*https://esto.nasa.gov/forum/estf2017/presentations/Osterman_A6P6_ESTF2017.pdf

Infrared Sounder

CubeSat Infrared Atmospheric Sounder (CIRAS)*

- Description
  - 6U Cubesat
  - Mass 8.5 kg Power 37.5 KW Data Rate 2 Mbps
  - Temperature and water vapor lower troposphere
  - Equivalent to AIRS (NASA) and CriS (NOAA)
- Technologies
  - Micro Pulse Tube Cryocooler (Lockheed Martin)
  - Spacecraft (Blue Canyon)
  - HOT-BIRD Detector (JPL)
  - Black Si. Blackbody (JPL)
  - GRISM Spectrometer (JPL)

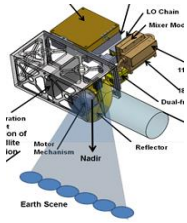


*https://www.jpl.nasa.gov/cubesat/missions/ciras.php Thomas Pagano, JPL

Microwave Radiometer

Microwave Atmospheric Sounder On CubeSat (MASC)*

Spatial: ±45° , 15 km (183) – 20 km (118)
Spectral: 8 Channels: 118-183 GHz
SWAP: <0.01 m³, 3 kg, 7 W, 10 kbps

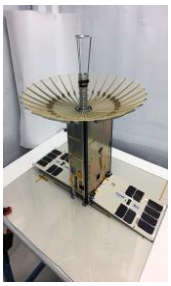


- Cross-track scanning (30 RPM) microwave sounder 118 GHz (oxygen) and 183 GHz water-vapor.
- 10 lbs. 6U CubeSat
- Uses MMIC-based millimeter-wave radiometers developed for GeoSTAR and HAMSR.
- Tested in PECAN campaign & OLYMPEX GPM validation campaign (on DC-8).
- Prototype for TEMPEST-D EVI-2

*Ken Wolfenbarger, Civil and Commercial Space Programs, NSTA, JPL Feb 6, 2015

RADAR

RainCube*



Ka-band Precipitation Profiler
2.5U Volume
Spatial: 5 km (Horiz) x 250m (Vert)
Spectral: 35.6 GHz
SWAP: 6U, 20 kg, 30 W, <1 Mbps

Ka-band parabolic antenna 0.5m
1.5U Volume (stowed).

Processing (Pulse Compression and Modulation)

Up/Down Converter

SSPA & Power Combiner

*https://www.jpl.nasa.gov/cubesat/missions/raincube.php

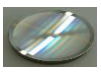
Visible Imaging

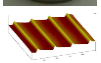
Snow and Water Imaging Spectrometer (SWIS)*

Spatial: ±5° , 0.28 km
Spectral: 228 Bands,
350 nm – 1.65 µm
SWAP: 6U¸, 9 kg, 15W, 5 Mbps

Miniature Dyson Spectrometer

JPL e-beam grating





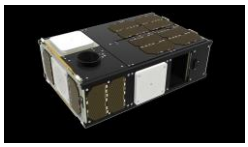
*https://esto.nasa.gov/forum/estf2014/presentations/B3P2_Mouroulis.pdf
*Ken Wolfenbarger, Civil and Commercial Space Programs, NSTA, JPL Feb 6, 2015

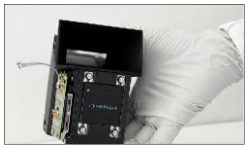
Hyperspectral Imaging

GomSpace GomX-4B*

Mass, Volume Power	1.1 kg, 1U volume compatible, 11 W
Spectral range	400- 1000 nm
Spectral bands	45
Resolution	4096 x 1850 pixels
Swath width (@300 km altitude)	164 km
GSD (Ground Sample Distance) (@300 km altitude)	40 m
Onboard data processing	Level 2

ESA & GomSpace (Denmark) Program





*https://directory.eoportal.org/web/eoportal/satellite-missions/g/gomx-4#foot4%29

HyperScout, provided by COSINE Measurement Systems, Warmond, The Netherlands,

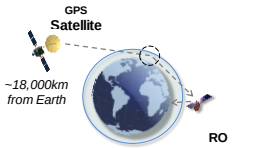
Radio Occultation

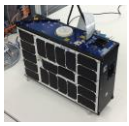
GeoOptics CICERO*

*Community Initiative for Continuing Earth Radio Occultation

CICERO

- Nano Satellites
- 6 → 24 → 48 → ?
- Cion Receiver
- Ground Command & Control
- Data Processing
- Products
  - High Resolution Atmospheric Profiles
    - Bending Angle
    - Refractivity
    - Density
    - Pressure
    - Temperature/Moisture
    - Absolute Measurement Heights
  - Ionospheric Electron Density
  - Global Temporal & Spatial avgs
  - Global pressure contours, gradients & geostrophic winds
- Replenishment & Updating





*Follow on to COSMIC