Current Earth Observing Satellites Operated by NASA

Session 4 (1 hr): Prof. Susan L. Ustin

Title: Overview of Airborne and Satellite Remote Sensing Instruments

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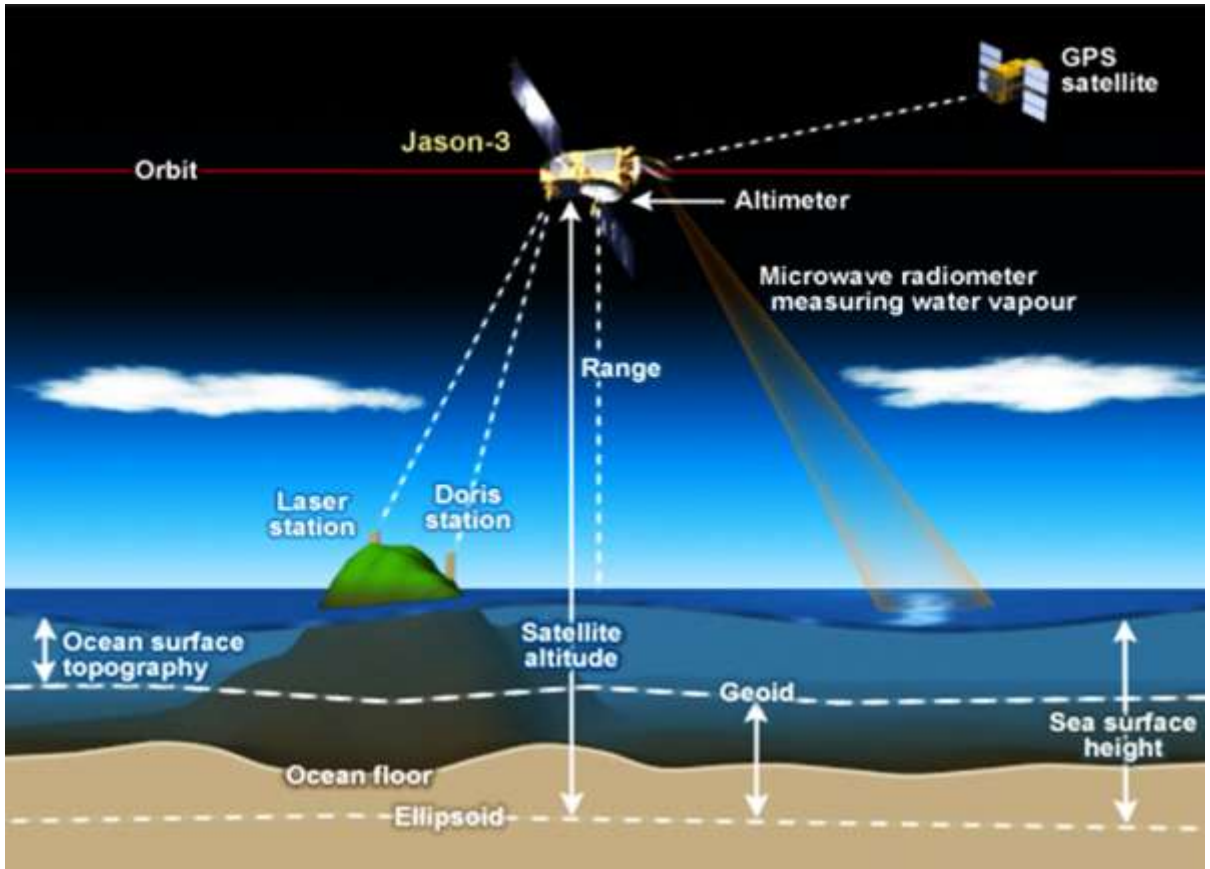
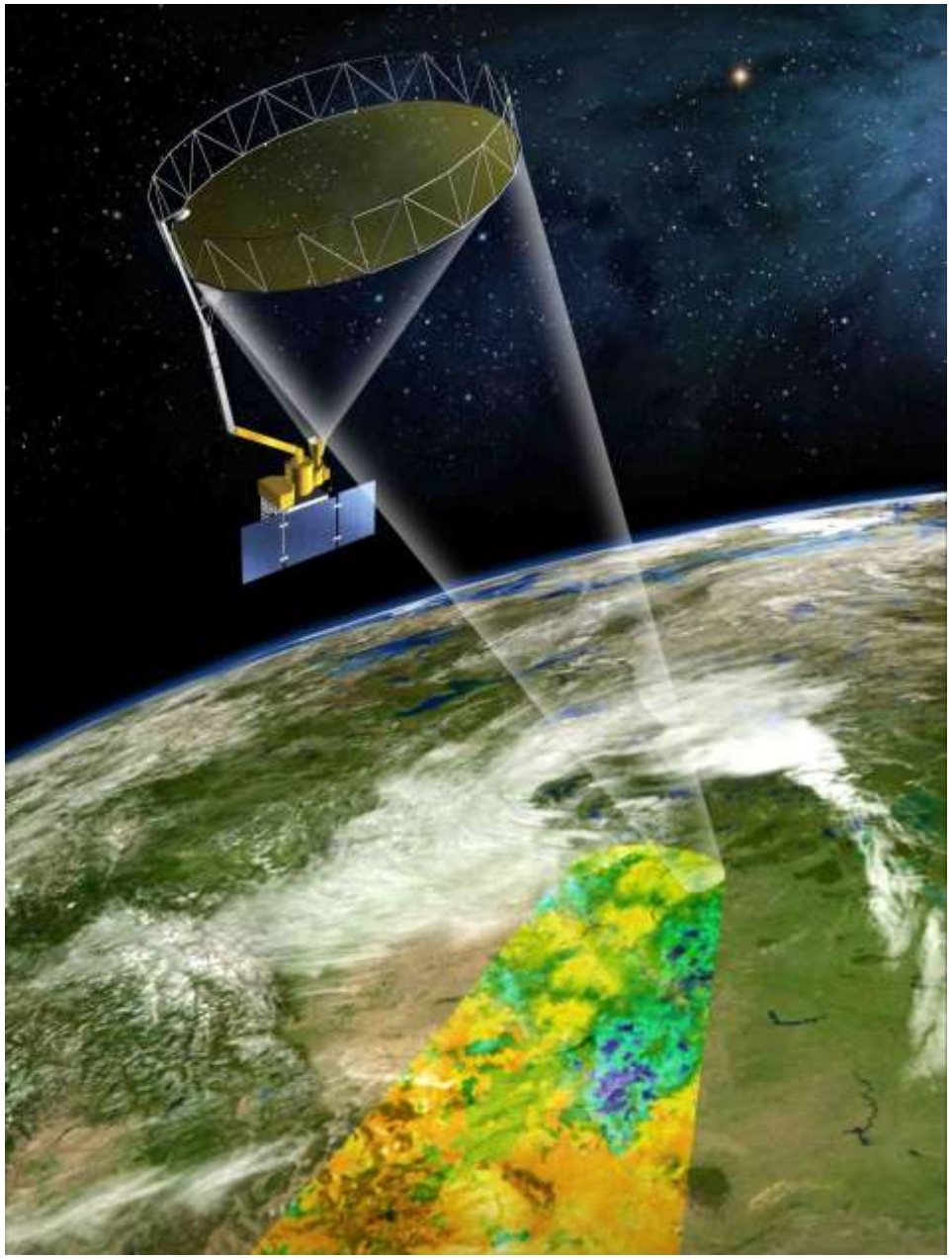
The Radar altimeter can measure accurately to 3.3 cm

Jason 3 launched Jan. 17, 2016 from Vandenberg AFB by Space X.

The series started with TOPEX/Poseidon Aug. 10, 1992 (joint program with NASA and CNES, French Space Agency)





SMAP Mission:
Soil Moisture Active Passive

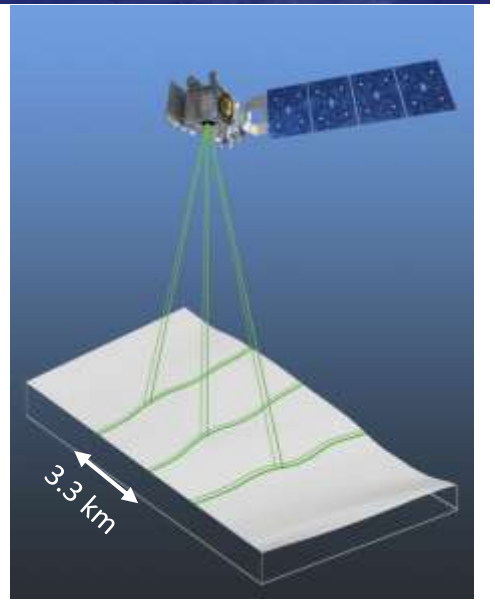
Launched: Jan. 31, 2015

- provide global measurements of soil moisture and its freeze/thaw state.
- enhance understanding of processes that link the water, energy and carbon cycles.
- extend the capabilities of weather and climate prediction models.
- quantify net carbon flux in boreal landscapes
- improved flood prediction and drought monitoring capabilities

SMAP included a radiometer and a synthetic aperture radar operating at L-band (1.20-1.41 GHz), with VV, HH, HV, at 1-3 km resolution;. **SAR failed soon after launch.**

Sentinel 1's C-band radar is not the only radar in space — or even the closest substitute for the L-band radar — but it is the only one that trails SMAP closely enough to gather timely radar images of the swath of Earth that SMAP covers -

ICESat-2 is the 2nd-generation of the orbiting laser altimeter ICESat, scheduled for launch in 2017.



3 pair of @532 nm beams measured at 70cm intervals

Science Objectives

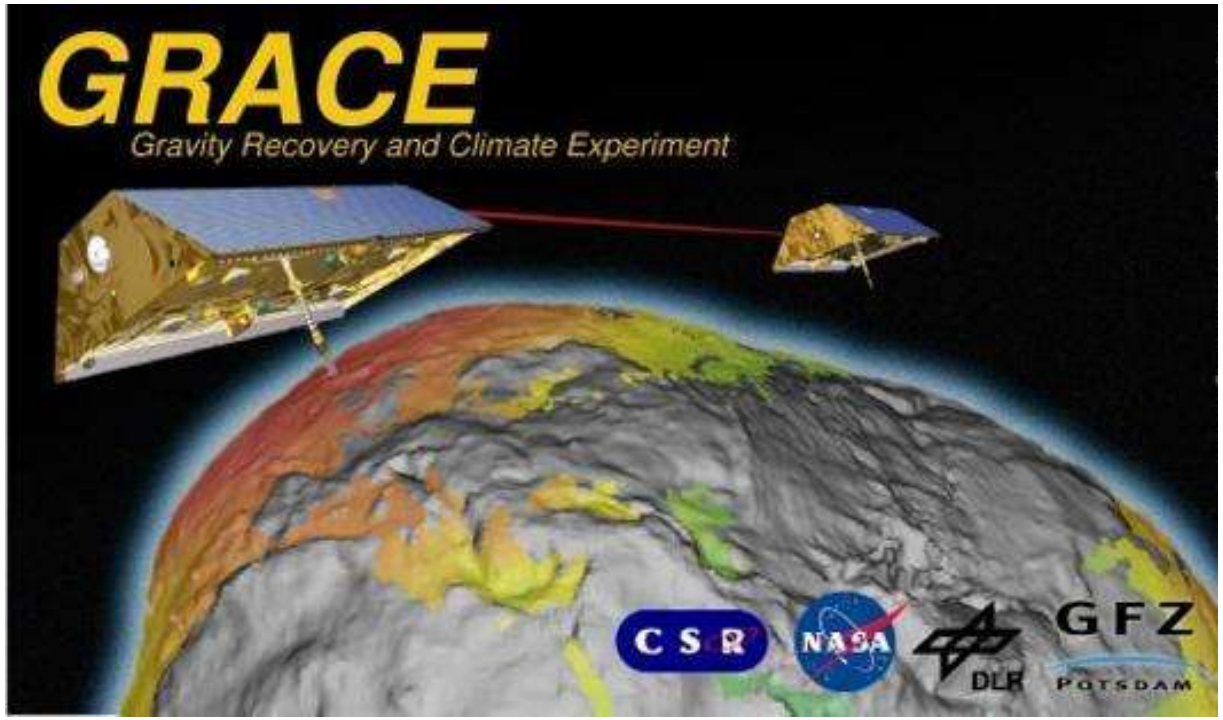
Quantifying polar ice-sheet contributions to sea-level change and the linkages to climate.

Quantifying regional signatures of ice-sheet changes to assess mechanisms driving those changes.

Estimating sea-ice thickness.

Measuring vegetation canopy height to estimate large-scale biomass and biomass change.

Enhance the utility of other earth observation systems through supporting measurements.



The Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) mission is a partnership between NASA and the German Research Centre for Geosciences (GFZ).

GRACE-FO will follow the GRACE mission, which was launched March 17, 2002. **Planned launch 2017**

Scientific Instrument(s)

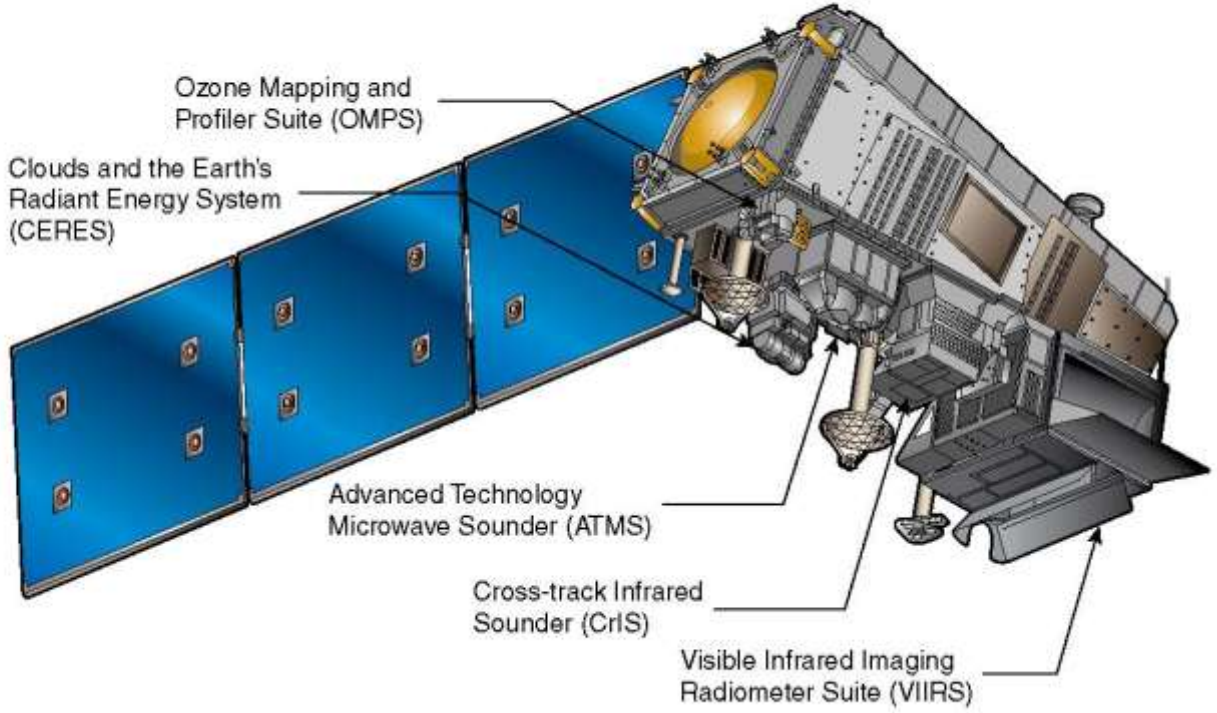
- Microwave K-band ranging instrument
- Accelerometers
- Global Positioning System receivers

The GRACE missions measure variations in gravity over Earth's surface, producing a new map of the gravity field every 30 days. Thus, GRACE shows how the planet's gravity differs not only from one location to another, but also from one period of time to another.

The Suomi National Polar-orbiting Partnership (Suomi NPP)

It is a Bridging Mission between the EOS program and the JPSS program: collects and distributes remotely-sensed land, ocean, and atmospheric data to the meteorological and global climate change communities as the responsibility for these measurements transitions from existing Earth-observing missions such as Aqua, Terra and Aura, to the JPSS.

It provides atmospheric and sea surface temperatures, humidity sounding, land and ocean biological productivity, and cloud and aerosol properties.

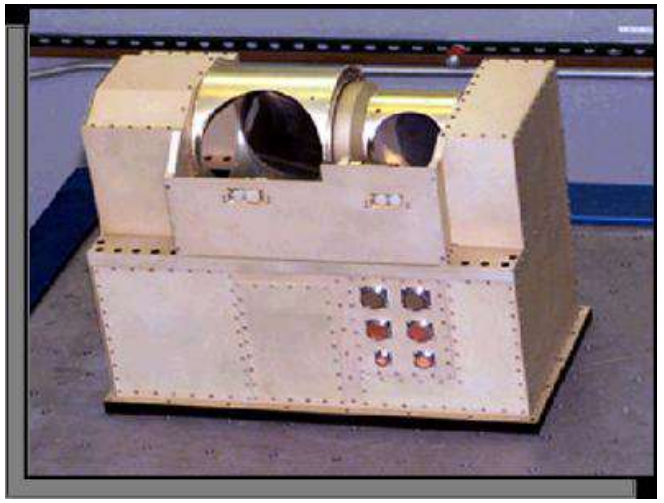


5 core instruments of the JPSS system

Launched October 28, 2011

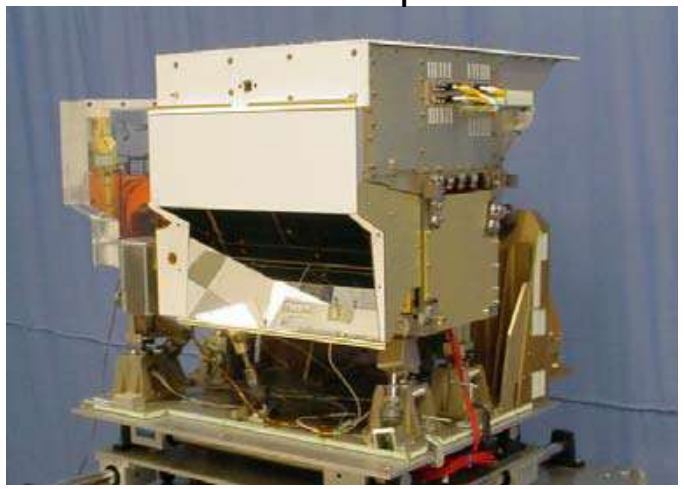
Joint Polar Satellite System program will operate this suite of weather instruments to 2038

Advanced Technology Microwave Sounder (ATMS)



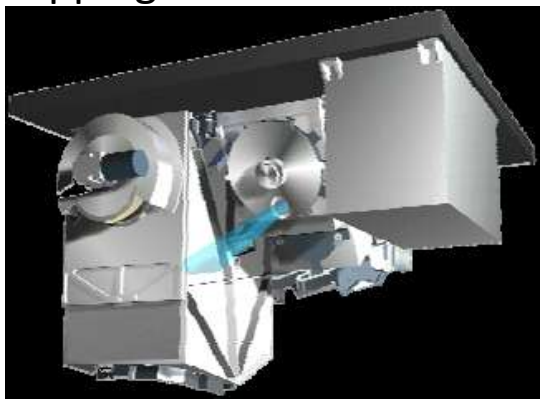
Includes channels of AMSU-A1, AMSU-A2, and AMSU-B

Cross-track Infrared Sounder (CrIS) with 1305 channels in SWIR, MIR and LWIR Fourier transform spectrometer



Water vapor and temperature profiles

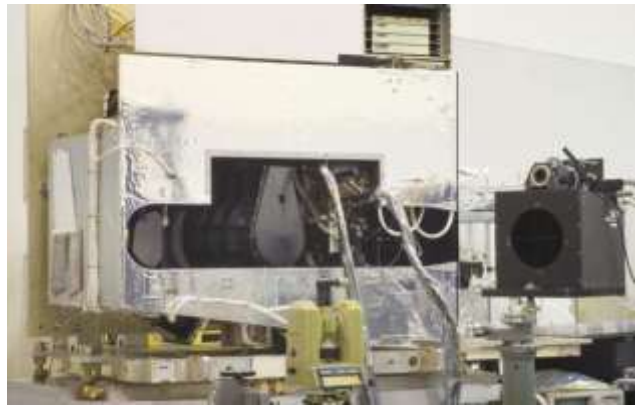
Ozone Mapping and Profiler Suite (OMPS)



Advanced hyperspectral suite provides improved vertical resolution and mapping heritage of TOMS

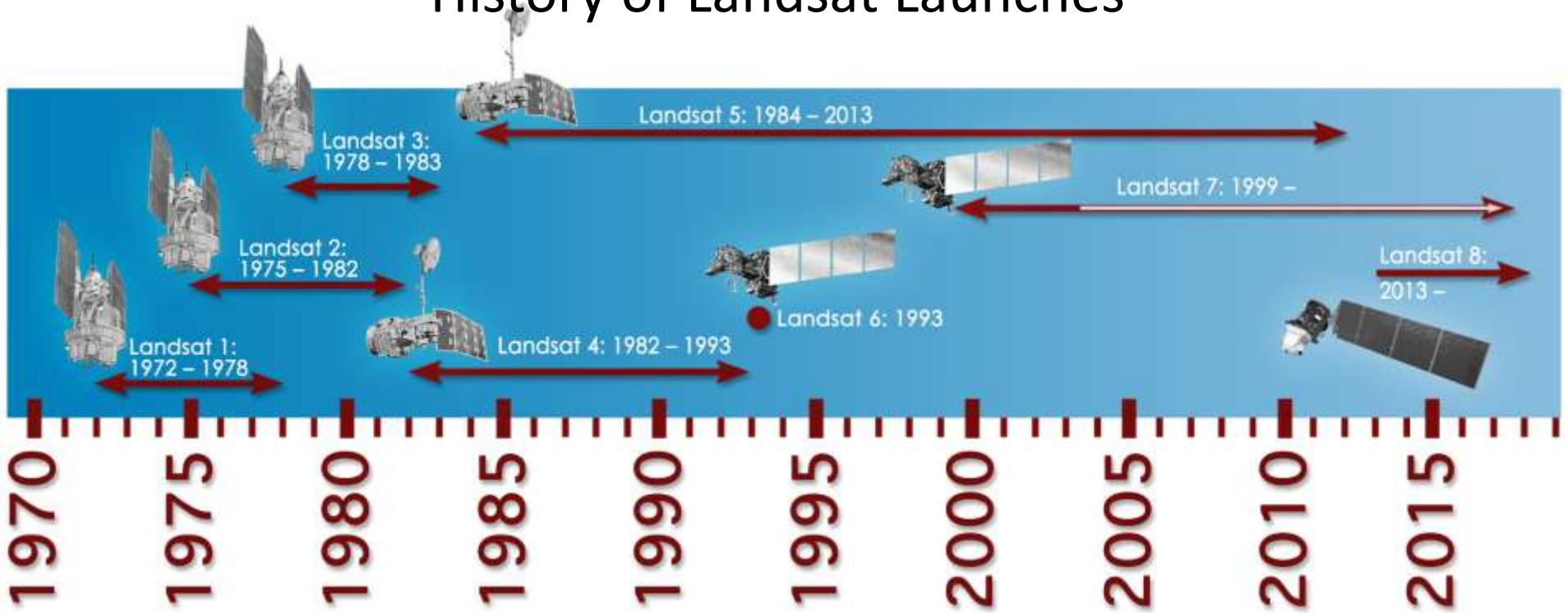
CERES, a 3-channel radiometer, measures budget radiation from the top of the atmosphere and cloud properties, heritage from ERB

Visible Infrared Imaging Radiometer Suite (VIIRS)



Heritage from AVHRR & MODIS

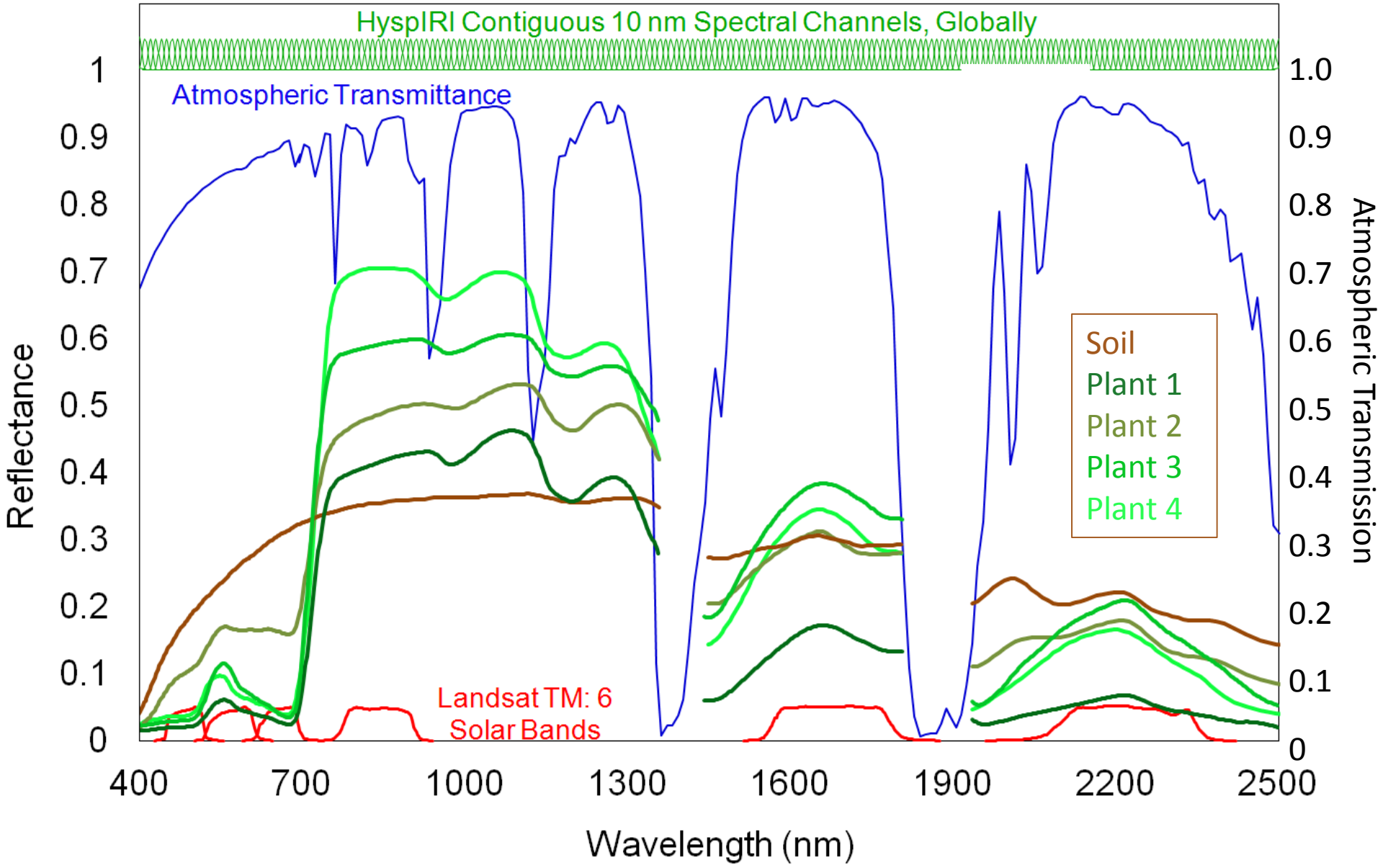
History of Landsat Launches



The Names Changed when a new sensor type was flown (note change in design):

Earth Resources Satellite (ERTS) 1, 2 Return Beam Vidicon (RBV) and MSS
Landsat 3 RBV and Multispectral Scanner (MSS)
Landsat 4, 5 MSS and Thematic Mapper
Landsat 6: failed on launch
Landsat 7 Enhanced Thematic Mapper; 2003 lost part of functionality
Landsat 8: Operational Line Imager

Imaging Spectrometer Data



What is an Imaging Spectrometer?

- **Imaging System**
- **Large # of bands**
- **Contiguous spectrum**
- **Airborne Examples:**

  AVIRIS-C, AVIRIS-ng

  CAO, NEON-AOP

  PRISM

  CASI

  AISA

  SpecTIR

  HYMAP

  APEX

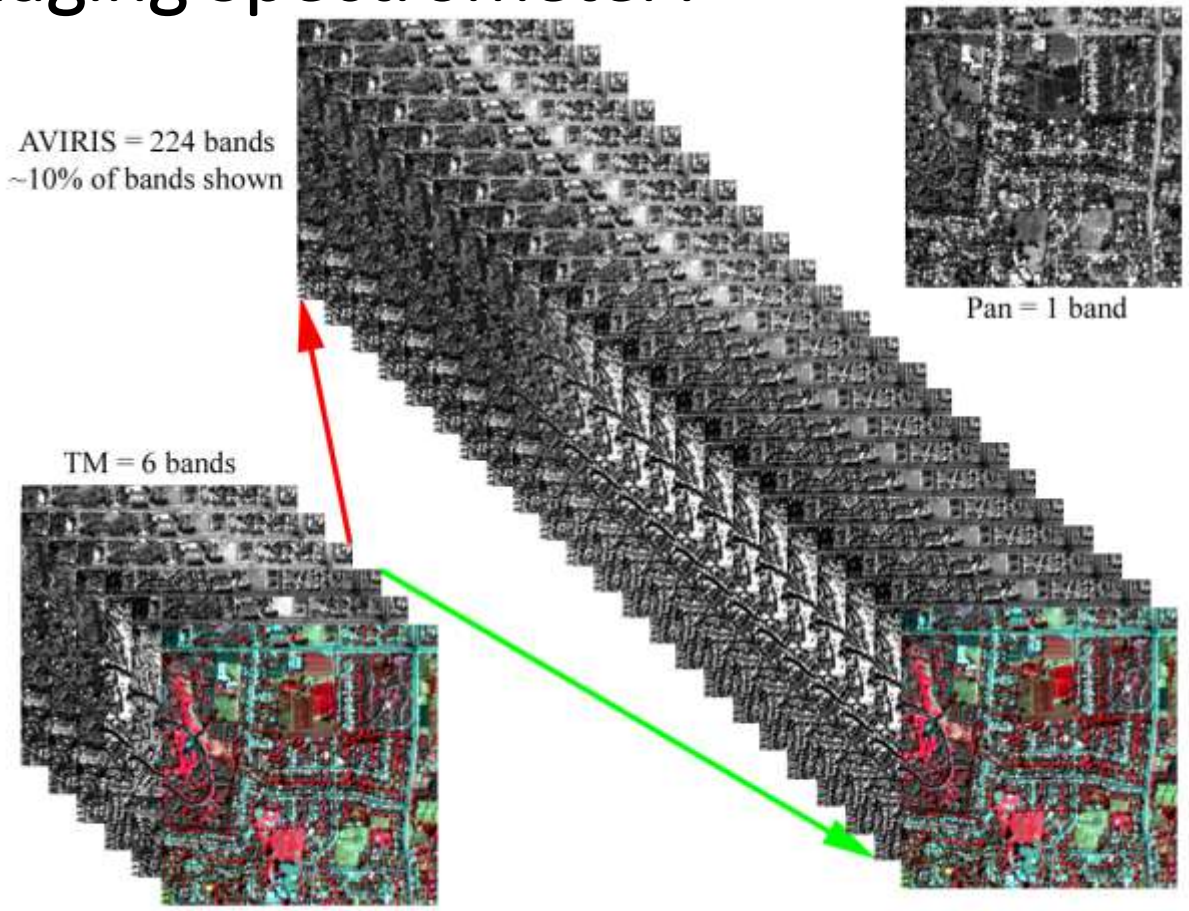
  Probe 1

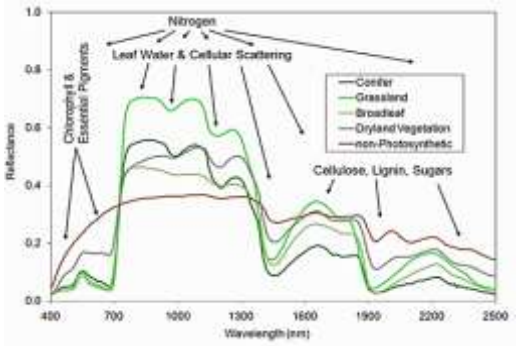
  HYDICE

***Satellite Examples**

Hyperion, PROBA

CRIS/PROBA





The German Spaceborne Imaging Spectrometer Mission; Scheduled launch: 2019; 5 yr mission

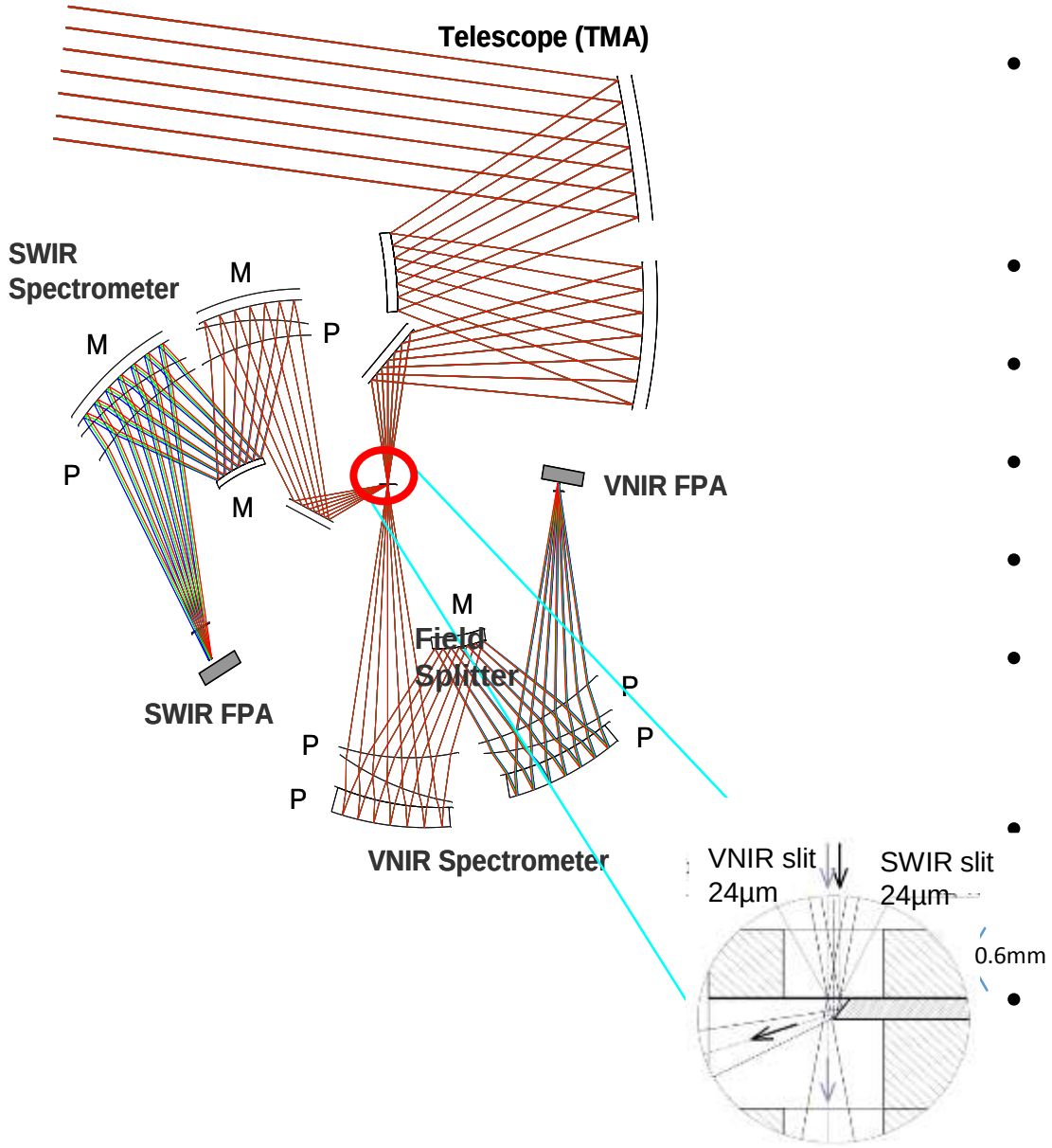
German hyperspectral satellite mission, aims at monitoring and characterizing the Earth's environment on a global scale.

EnMAP will measure and provide data to model key dynamic processes of the Earth's ecosystems by extracting geochemical, biochemical and biophysical parameters, which provide information on the status and evolution of various terrestrial and aquatic ecosystems.

Mission Outline

- Dedicated imaging pushbroom hyperspectral sensor;
- Broad spectral range from 420 -1000 nm (VNIR) and from 900 - 2450 nm (SWIR) with high radiometric resolution and stability
- Swath of 30km , pixel resolution of 30 m and off-nadir (30°) pointing (4 day repeat)
- On-board memory to acquire 1,000 km swath length per orbit and 5,000 km per day.

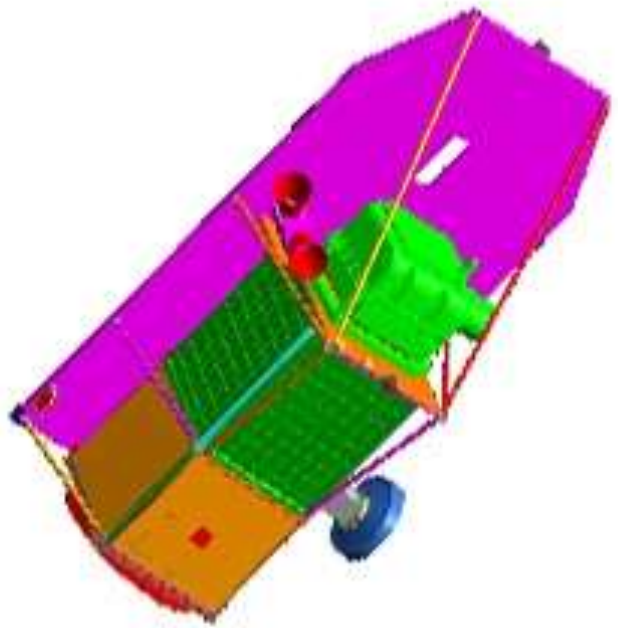
EnMAP Hyperspectral Imager



- EnMAP is an environmental research satellite focused on process oriented land surface dynamics
- PI: Charly Kaufmann, GFZ Potsdam
- Launch scheduled for mid 2019
- 30 km Swath, 30m spatial resolution
- 5-10 nm spectral bandwidth
- Level 2 Product: Ortho-rectified and atmospherically corrected data
- Strong scientific user support planned: Toolbox, Spectral Archive
- Open for international partnerships with respect to data utilization
- Information: http://www.enmap.org

PRISMA: Precursore IperSpettrale (Hyperspectral Precursor) of the application mission

Italian Space Agency's Technology Demonstration Hyperspectral Imager



Characteristics of the System:

- A satellite in LEO SSO (700 620 km) orbit
- 5-year technology demonstration
- "Average" daily imaging capability Satellite
- "Small" satellite (<7500kg),
- Space resolution: 20-30 m (Hyp) / 2.5-5m (PAN)
- Swath width: 30 km
- Spectral range: 0.4 - 2.5 µmm (Hyp) / 0.4 - 0.7 µm (PAN)
- Continuous coverage of spectral ranges with 10 nm bands
- The satellite launch is foreseen by the end of the **2019**

3 Earth System Science Pathfinder (ESSP) Program Earth Venture Class Missions

Planned for the ISS in 2018 and 1 JAXA hyperspectral imager

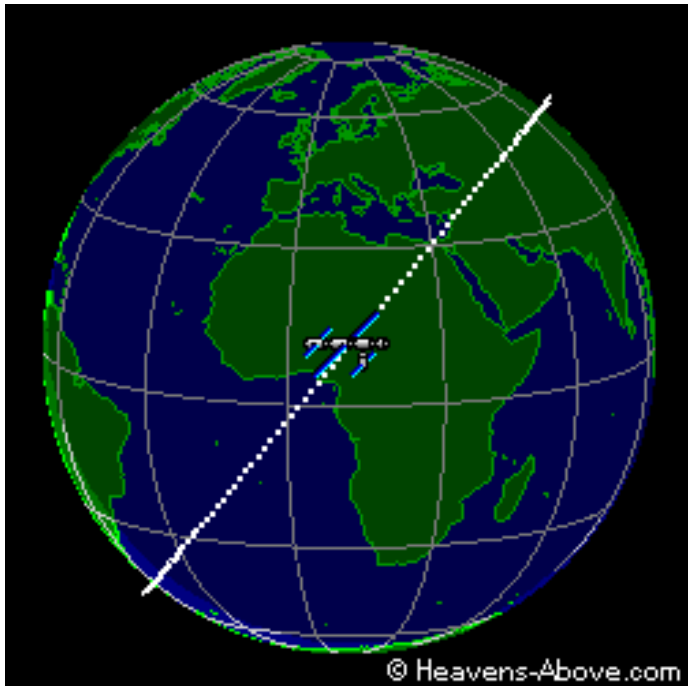
ISS characteristics:

Low earth orbit: 409-416 km (elliptical orbit)

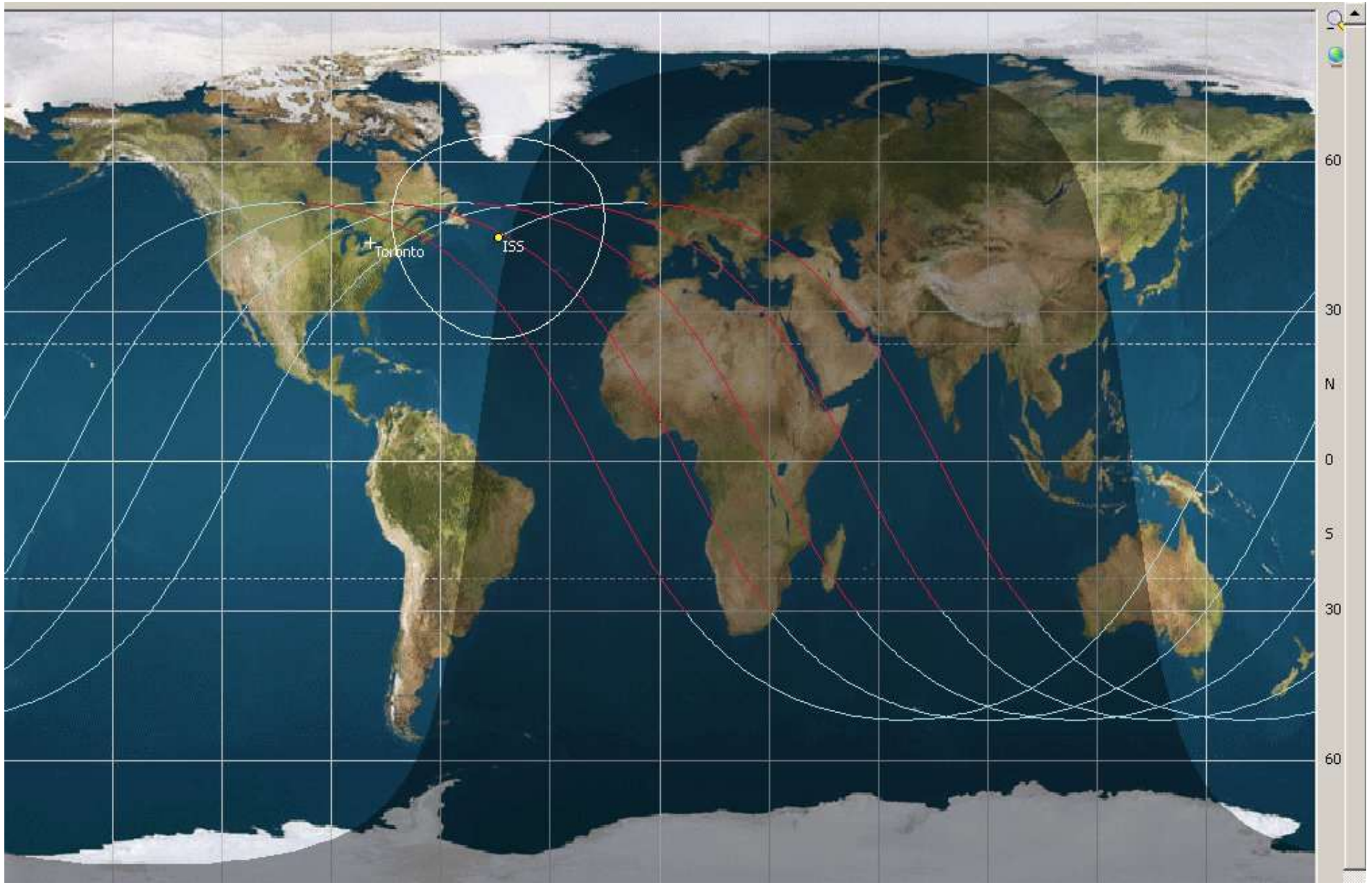
Orbital period: 92.69 min.

Orbital inclination: 51.65º

Japanese Experiment Module- Exposed Facility (JEM-EF)



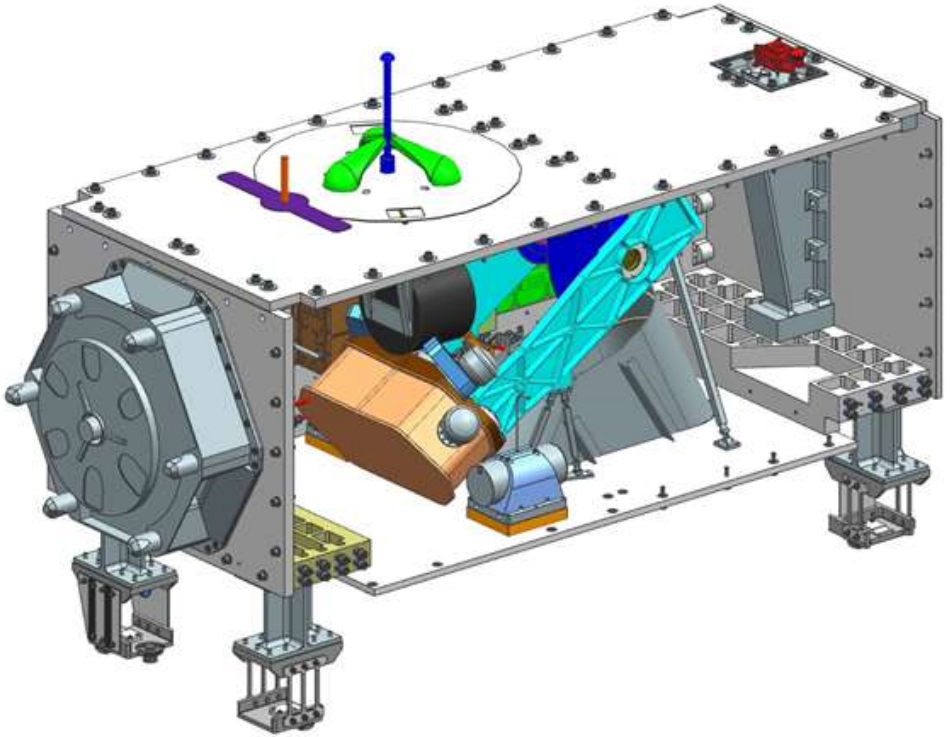
International Space Station 51° Orbit



5 Earth System Science Pathfinder (ESSP) Program Earth Venture Class Missions Planned for the ISS in 2018 and 2019

1st Mission Global Ecosystem Dynamics Investigation Lidar GEDI (Ralph Dubayah, U. MD)

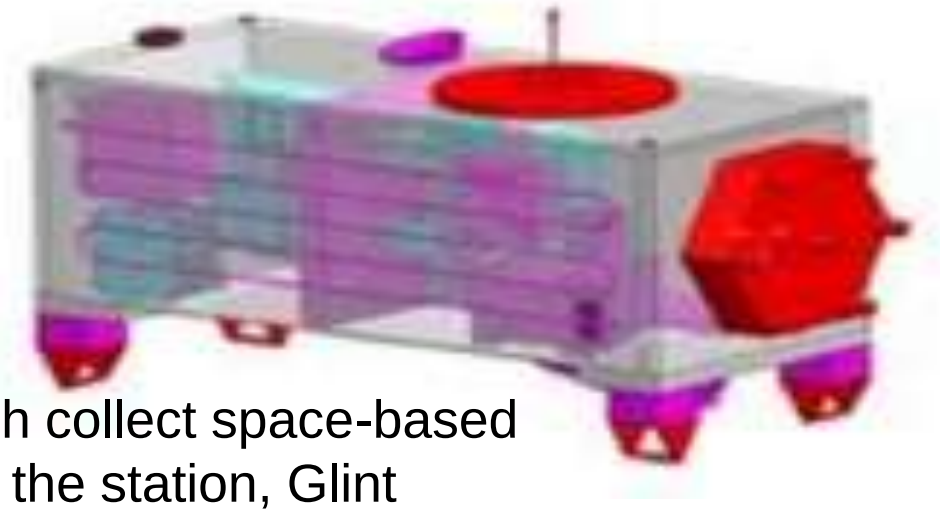
The goal of this mission is to characterize the effects of changing climate and land use on ecosystem structure and dynamics to enable radically improved quantification and understanding of the Earth's carbon cycle and biodiversity. It is focused on tropical and temperate forests, with data from 3 laser transmitters to produce 14 parallel tracks of 25 m footprints



2nd Mission: ECOStress: ECOsystem Spaceborne Thermal Radiometer Experiment on on the Space Station (Simon Hook, JPL)

This mission addresses critical questions on plant–water dynamics and future ecosystem changes with climate through an optimal combination of 4-band thermal infrared (TIR) measurements and 1 SWIR band over the diurnal cycle for a wide range of biomes with high spatiotemporal resolution from the International Space Station.

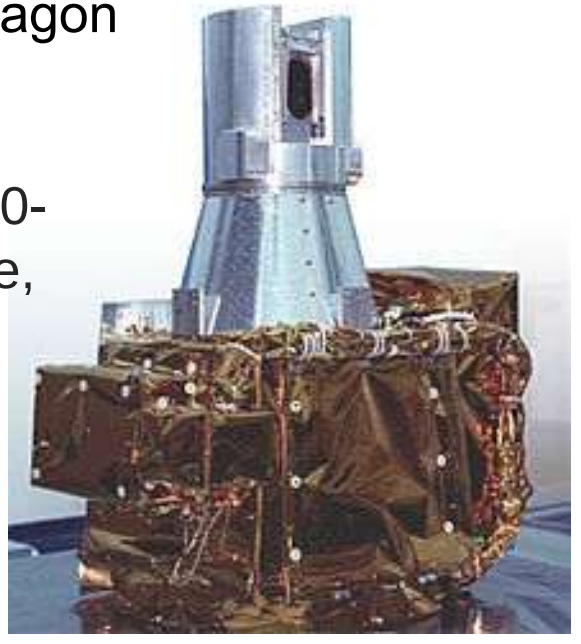
3rd Mission: The Orbiting Carbon Observatory 3, or OCO-3 (Annmarie Eddering, Jet Propulsion Laboratory)



Following the design of OCO-2, it will investigate questions about the distribution of CO_2 on Earth as it relates to growing urban populations and changing patterns of fossil fuel combustion.

The OCO-3 consists of 3 high resolution grating spectrometers which collect space-based measurements of atmospheric CO_2 in 3 modes. Nadir Mode, below the station, Glint Mode, where sunlight is directly reflected off the Earth's surface and Target Mode, which views a specific target continuously as the space station passes overhead.

5th Mission: The SAGE III was Launched Feb. 19, 2017 to the ISS on SpaceX's Dragon Spacecraft.



It is a 4th generation atmospheric instrument UV-VIS; 290- 380nm) and VIS-NIR (380-1030nm) to measure clouds, aerosols (@1550nm), water vapor, ozone, temperature, pressure, and NO_2, NO_3, and OClO.

The sensor consists of pointing and a UV/visible spectrometer imaging system, with continuous spectral coverage between 290 and 1030 nm. And a discrete photodiode at 1550 nm for aerosols.

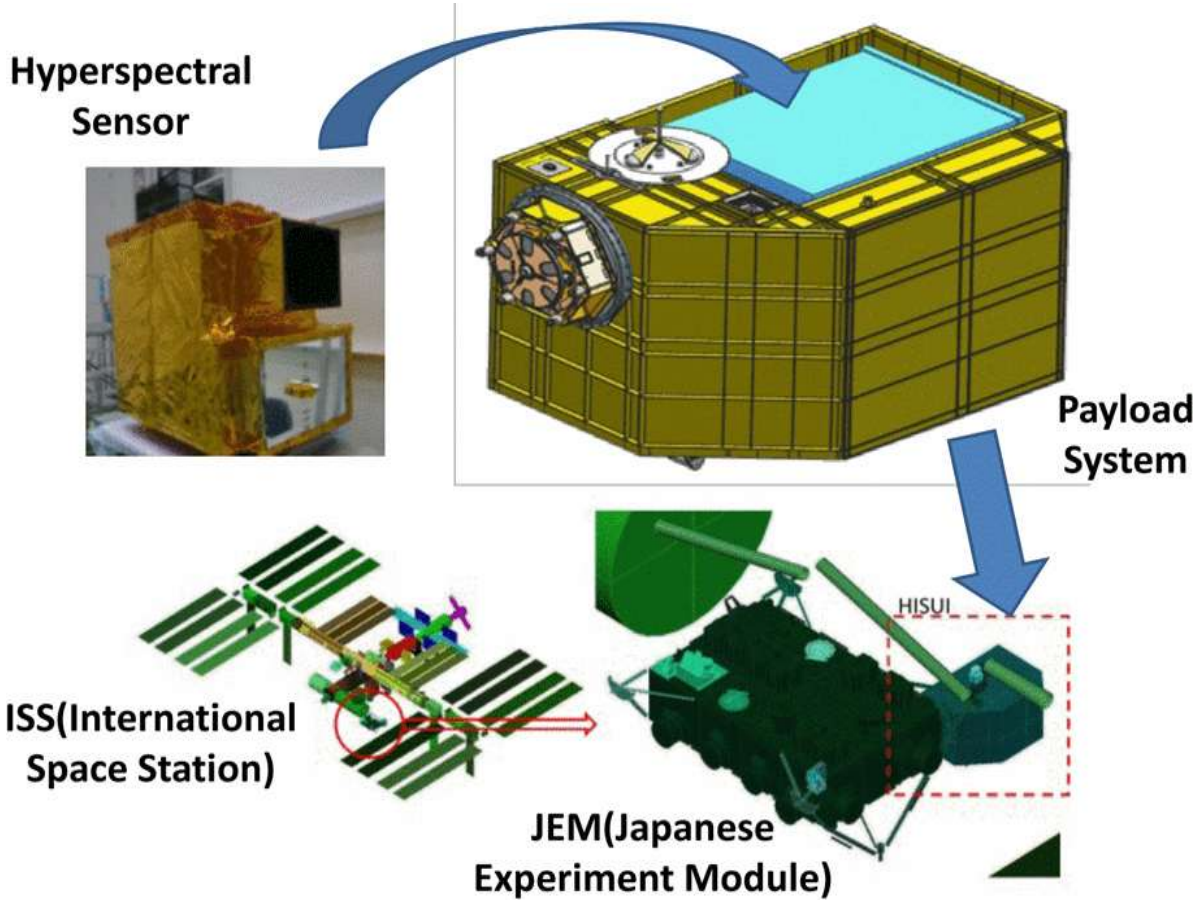
Kingfisher Jadeite

4th ISS Mission: Hyperspectral Imager Suite (HISUI) is developed by the Japanese Ministry of Economy, Trade, and Industry (METI).

A Successor of Terra ASTER

The objective of HISUI onboard the ISS in 2018-2019, is to start full-scale practical application development for hyperspectral remote sensing. It is a hyperspectral VSWIR imager with high spatial resolution. Expected launch in 2018-2019.

- 30m pixels
- 185km swath
- 400-2500nm, in 10-12.5nm bands
- 12 bit data
- No data policy announced



SubOrbital: Portable Remote Imaging Spectrometer (PRISM)

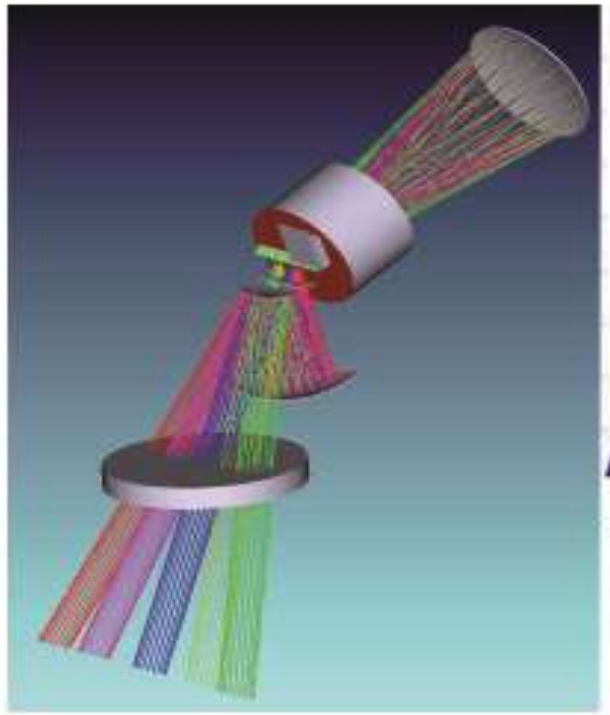
P. Mouroulis, PI and D. Cohen, PM (JPL)

- Simple and robust airborne pushbroom imaging spectrometer
- High SNR, high uniformity, low polarization
- 350-1050 nm, 1240 nm, 1610 nm
- Eventual NASA facility instrument
- Specially designed for the challenges of airborne coastal ocean remote sensing

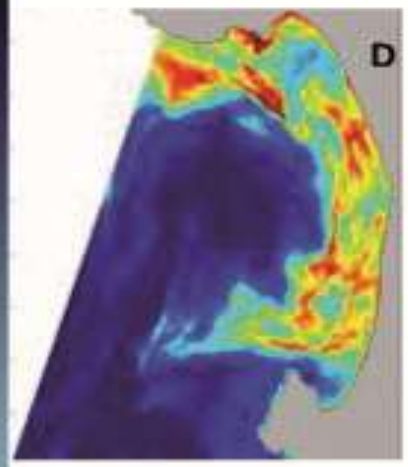
Science targets:

- Coastal habitats
- Sediment plumes
- Algal blooms
- Episodic hazards
- Lake, river, estuary water quality

- Project start 09/09, delivery 06/12



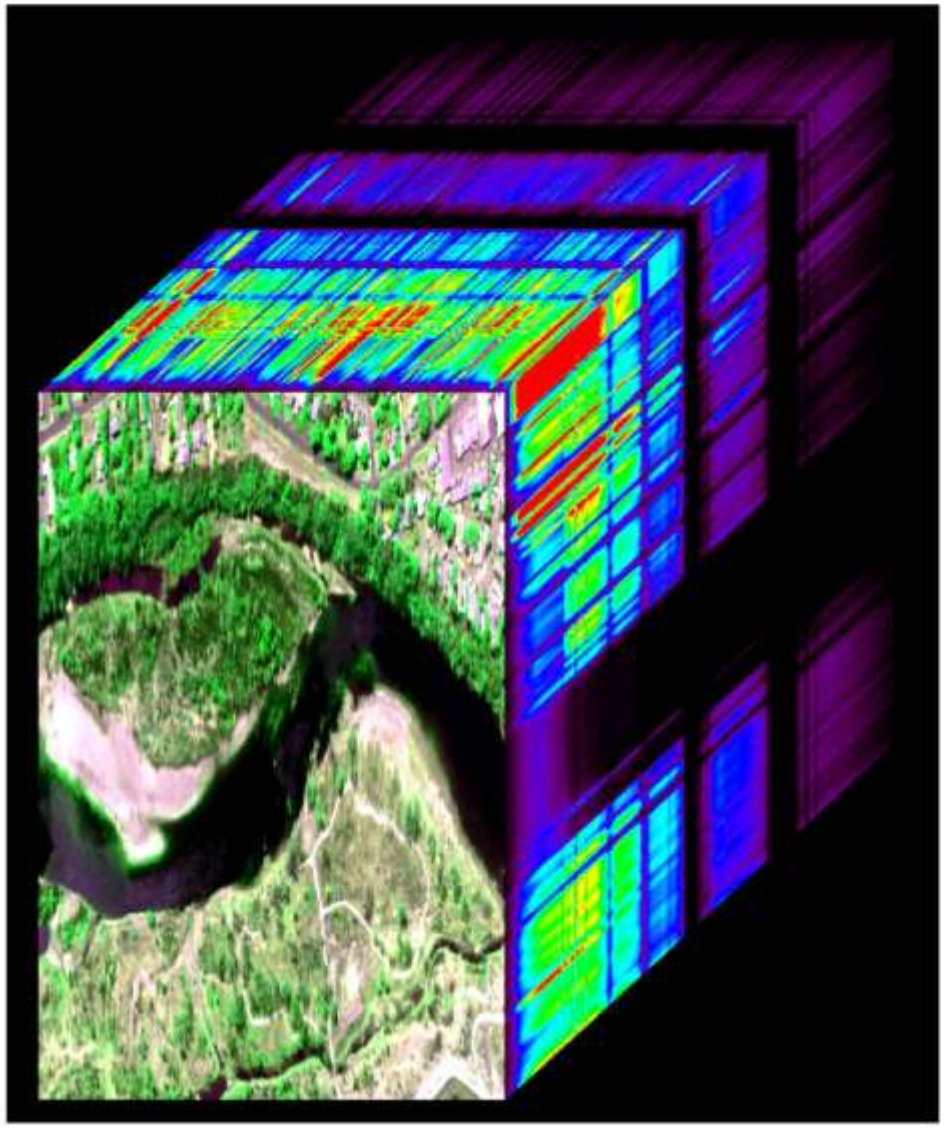
PRISM design

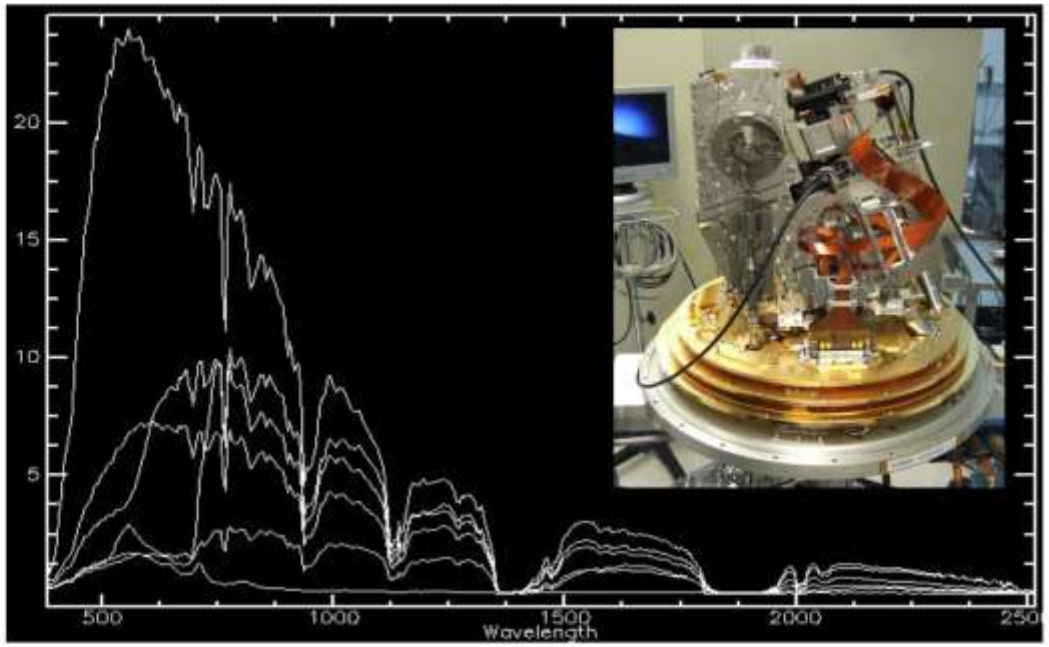


Algal bloom over Monterey Bay (AVIRIS data)

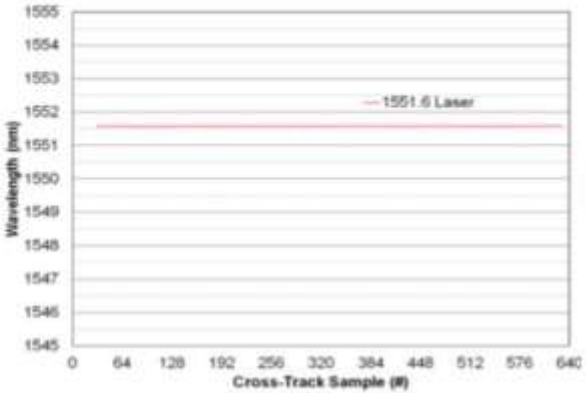
PRISM precursor Dyson spectrometer testbed shows approx. spectrometer size

SubOrbital: NASA AVIRIS Next Generation Instrument, May 2012

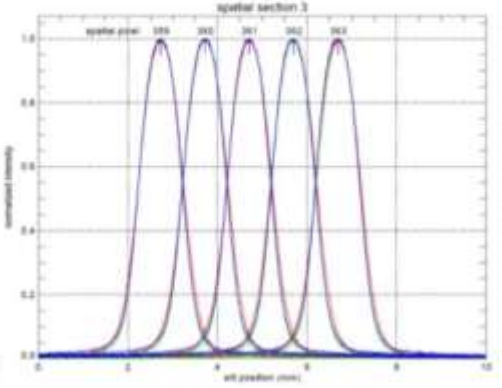




Spectral X-track Uniformity > 95%

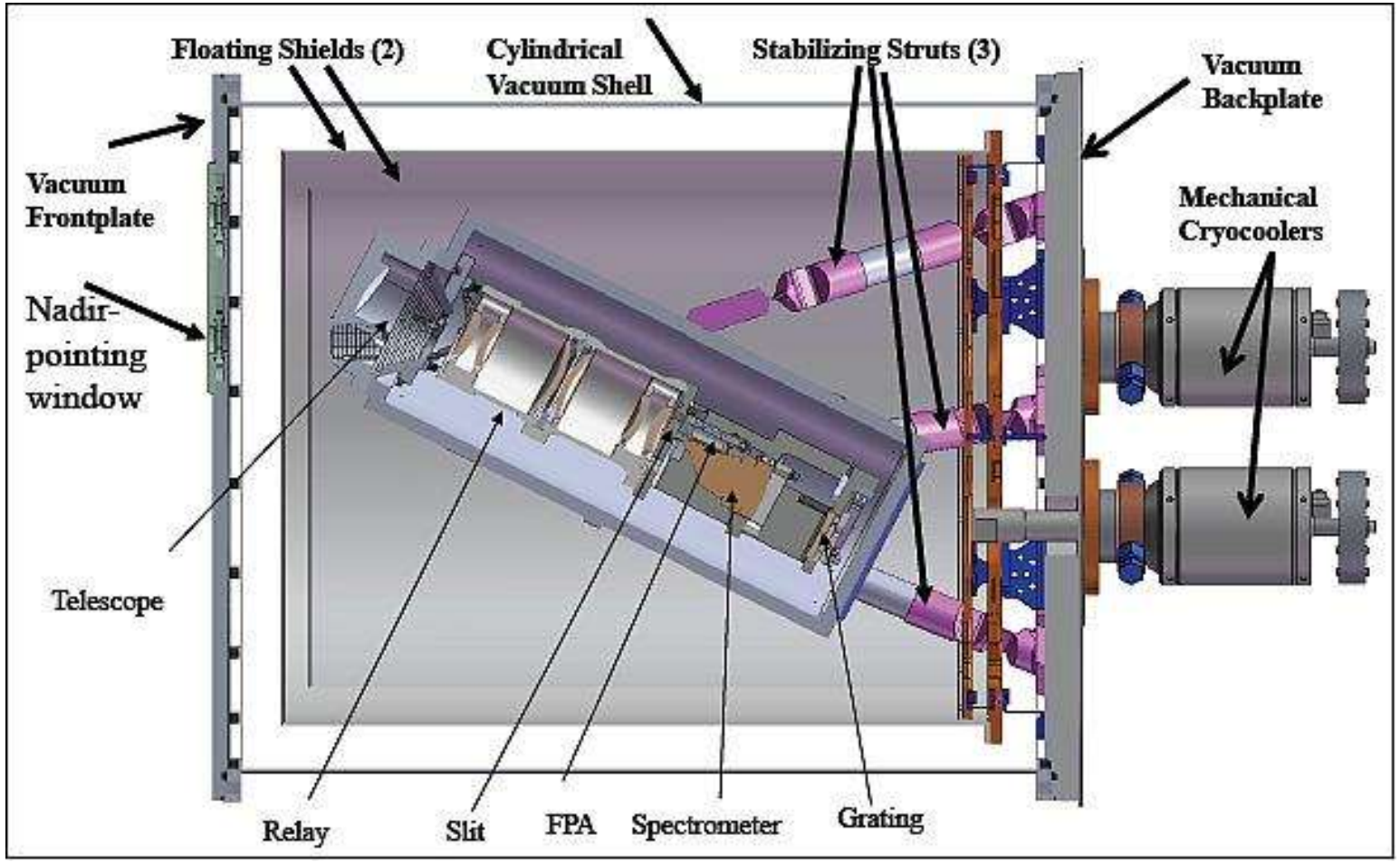


Spectral IFOV Uniformity > 95%



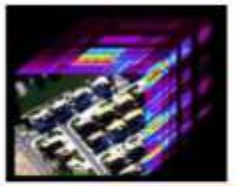
5 nm bands 380-2500nm, 457 bands

Sub-Orbital HyTES - A New Hyperspectral Thermal Emission Imaging Spectrometer

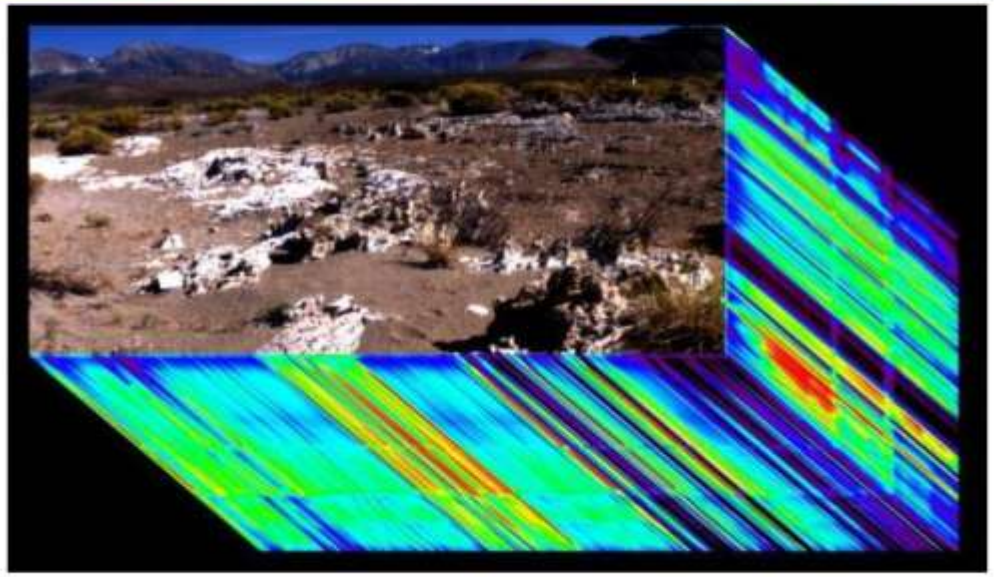


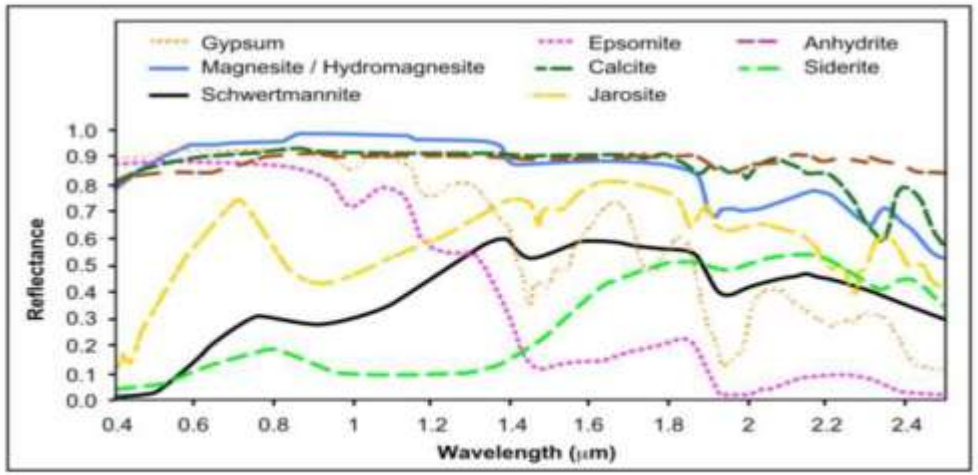
http://hyspiri.jpl.nasa.gov/downloads/2012_Workshop/day3/15_Hook-2012-10-17-HyTES.pdf

2012 Ultra Compact Imaging Spectrometer (UCIS) <3kg < 3W



Miniaturized Imaging Spectrometers

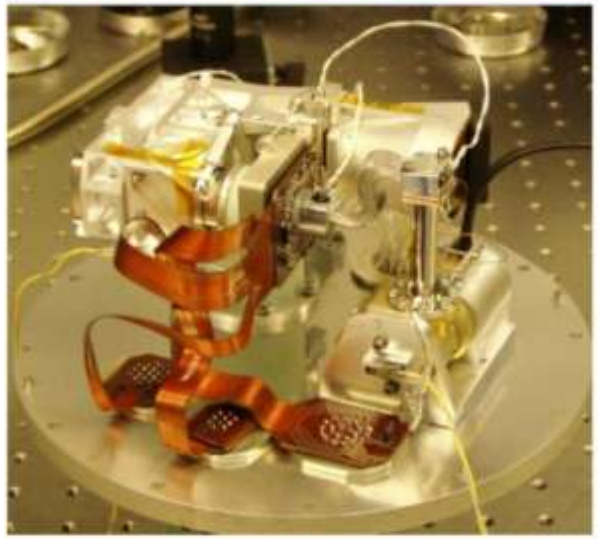




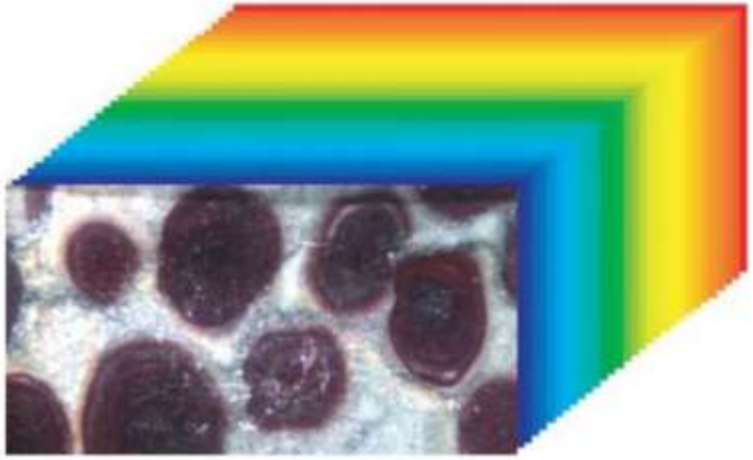
R.O. Green 2013. Understanding Worlds Through 30 Years of Spectroscopy SDW2013 **Robert** O **Green** Imaging Spectroscopy 131009a.pdf

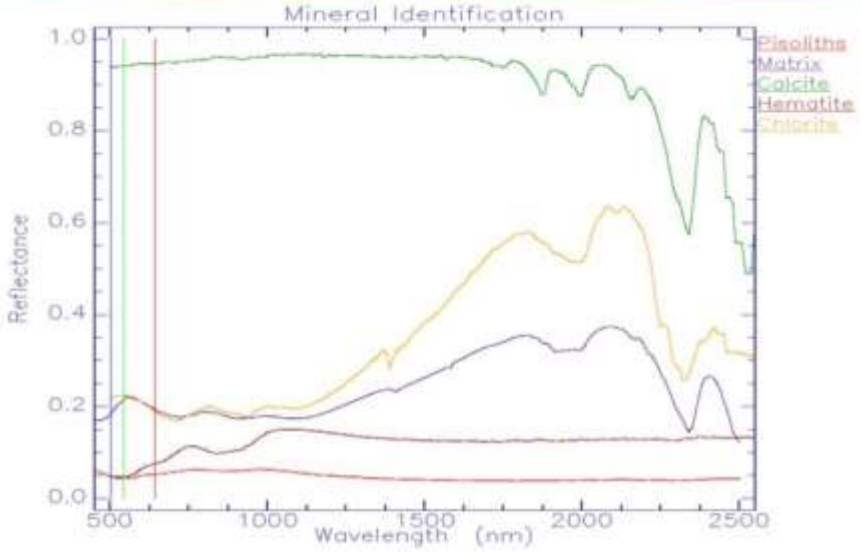
Miniaturized Imaging Spectrometers

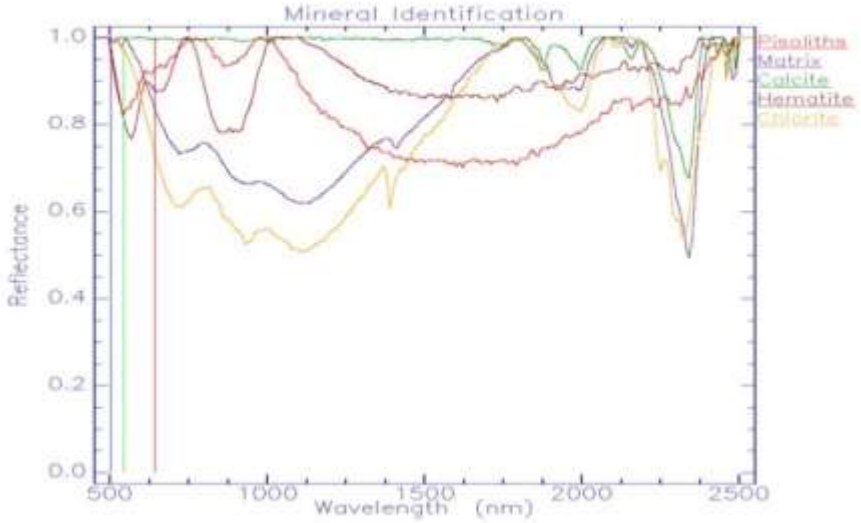
2012 Micro Scale Imaging Spectroscopy with UCIS



Pisolithic Ironstone with <100 µm spot





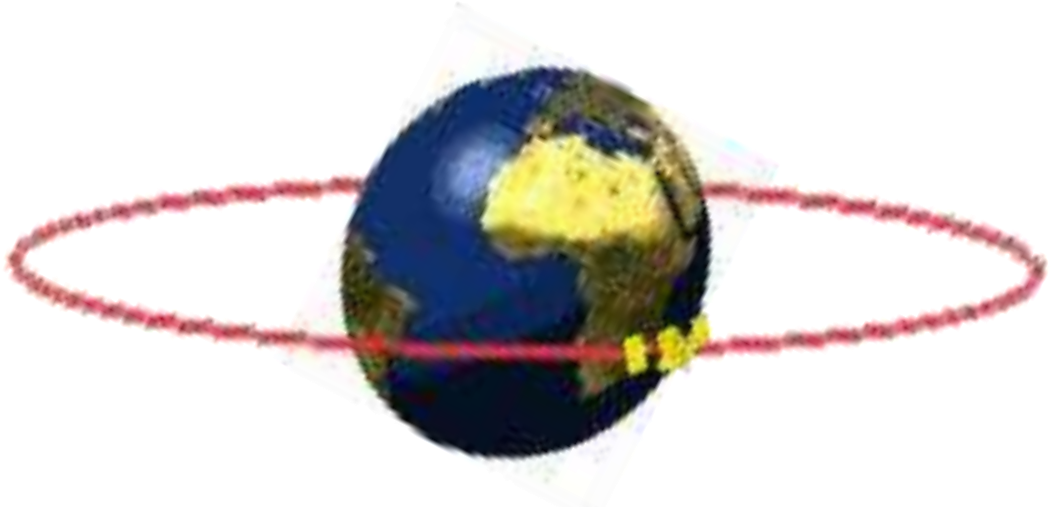


R.O. Green 2013. Understanding Worlds Through 30 Years of Spectroscopy
SDW2013 **Robert** O **Green** Imaging Spectroscopy 131009a.pdf

Geostationary Operational Environmental Satellite (GOES)

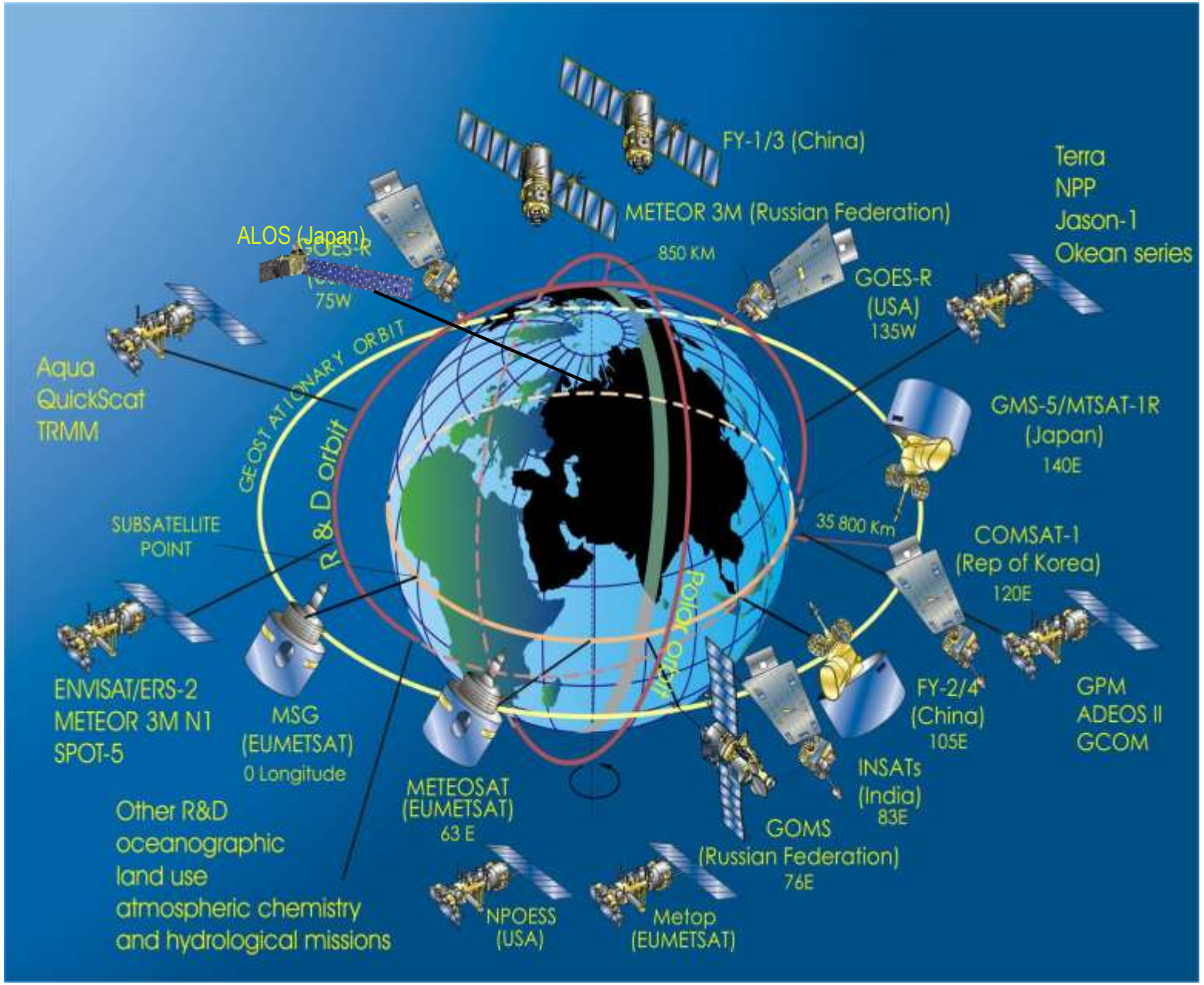
International Coordinated Weather Satellites

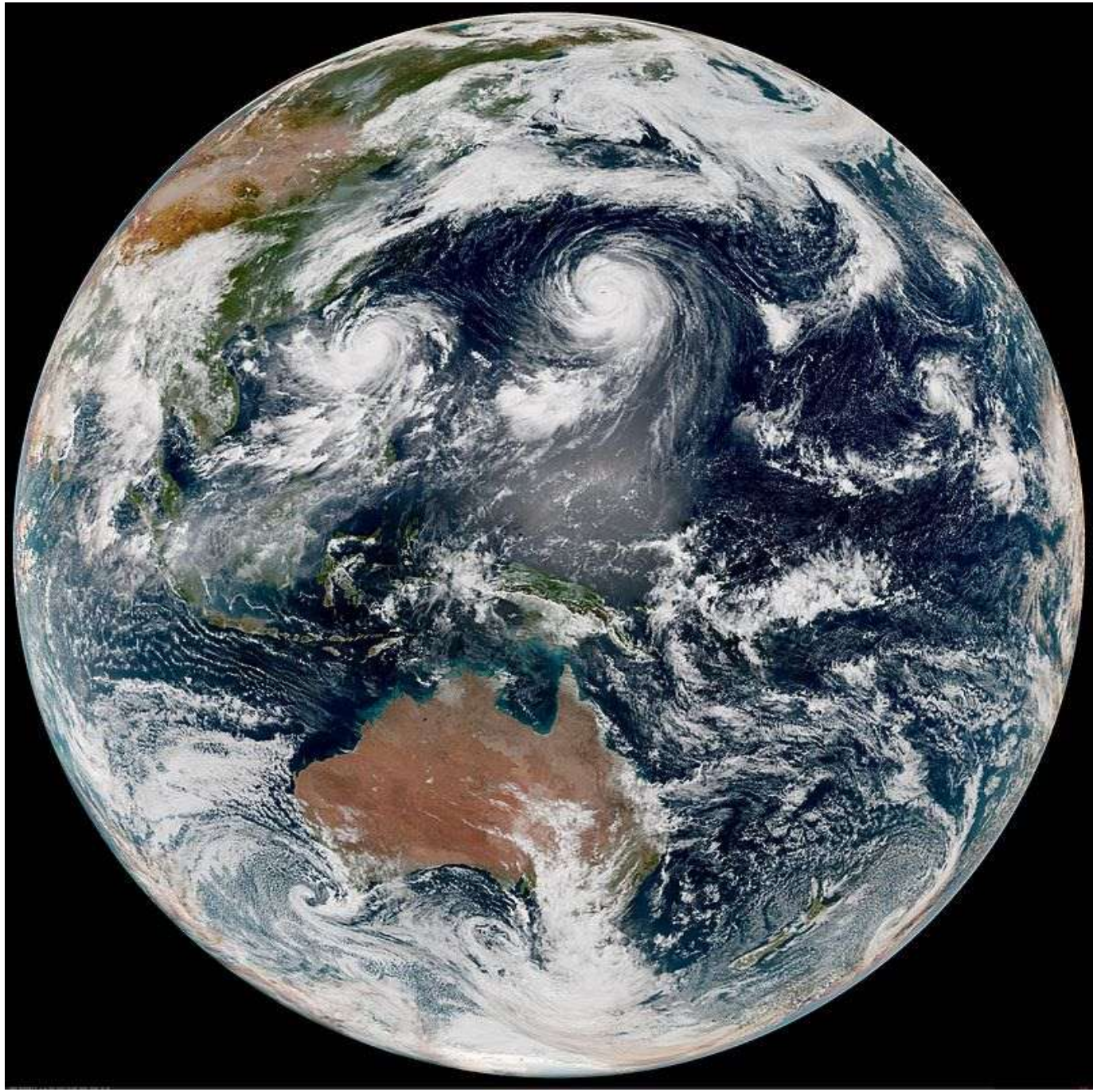
Each one measures about 20% of the Earth's disk.



Orbit at a speed to match the rotation of the earth.
Complete one rotation per 24 hrs.

International Coordinated Weather Satellite Programs





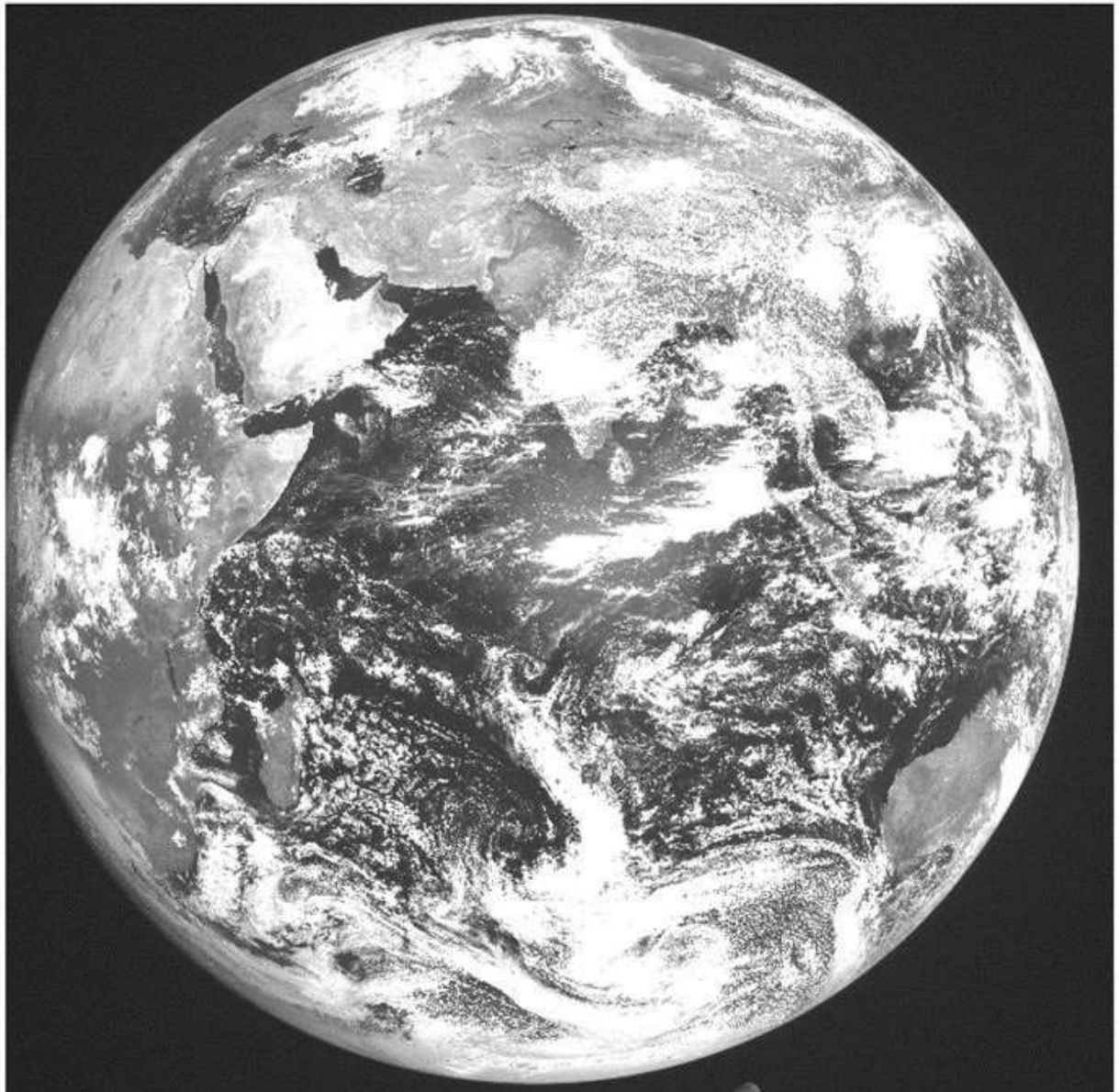
JMA Himawari Series GEO Satellites

Himawari 8, is an Advanced 16 channel multispectral imager that captures resolution down to 500m and can provide full disk observations every 10 mins and image the entire Japan territory every 2.5 minutes. It became operational 7 July 2015 and is the successor to the MTSAT-2.

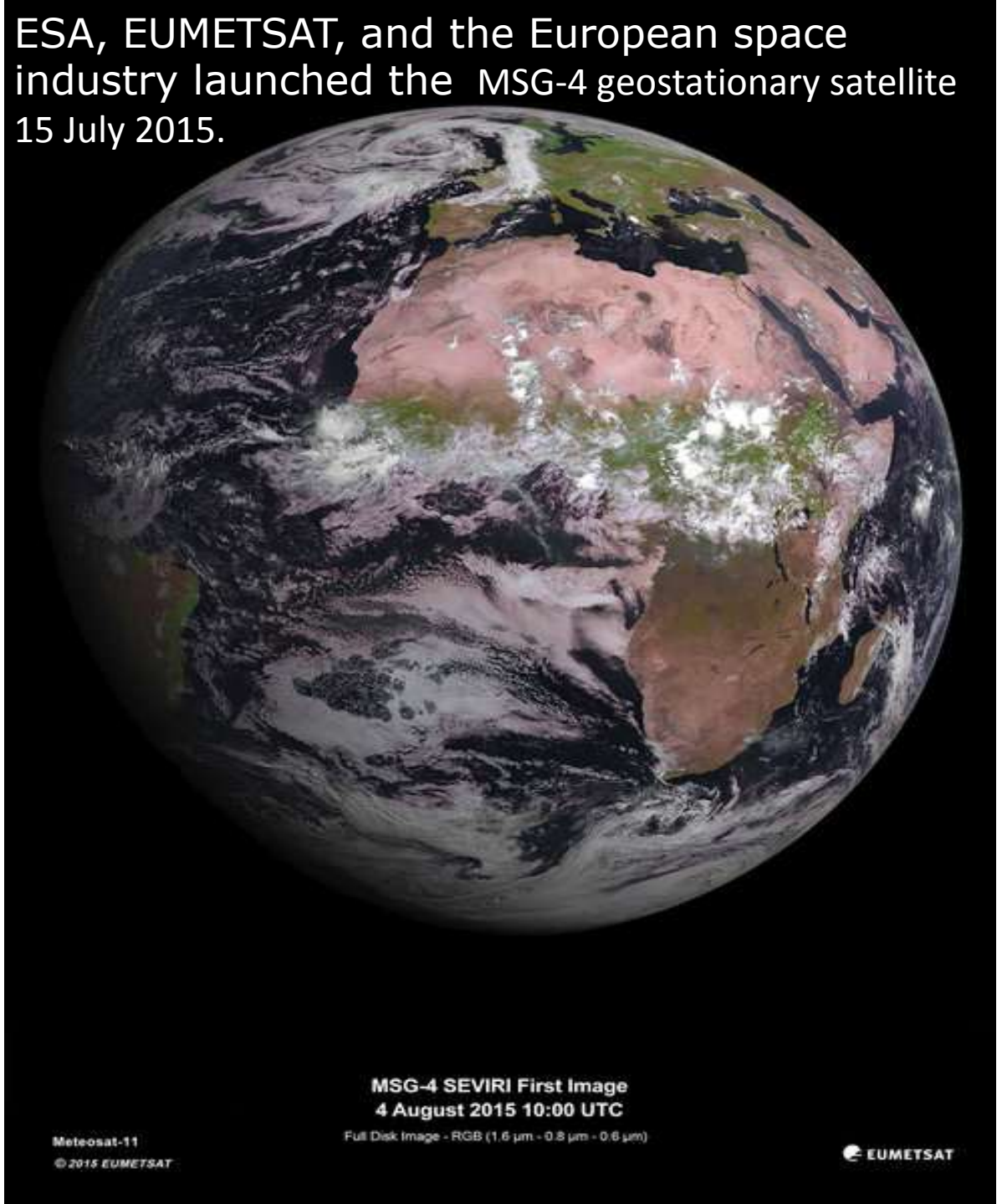
This is a Rayleigh-corrected, true-color full disk image from the AHI sensor.

Himawari 9, identical to Himawari 8, was launched on 2 November 2016 and put in stand-by orbit until 2022, when it succeeds Himawari 8.

Indian Space Agency's (ISRO) advanced Geostationary INSAT-3DR, launched 8 September 2016.
Cloud cover over India as seen in a visible band on INSAT-3D on 15 Sept. 2016, 11:30 IST

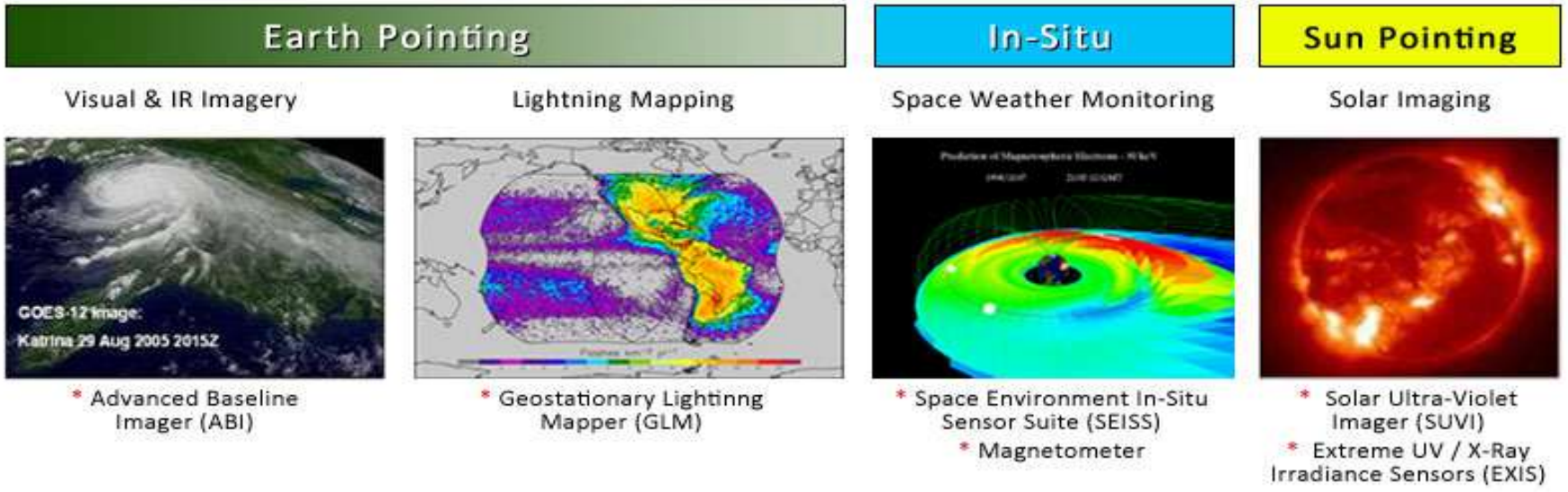


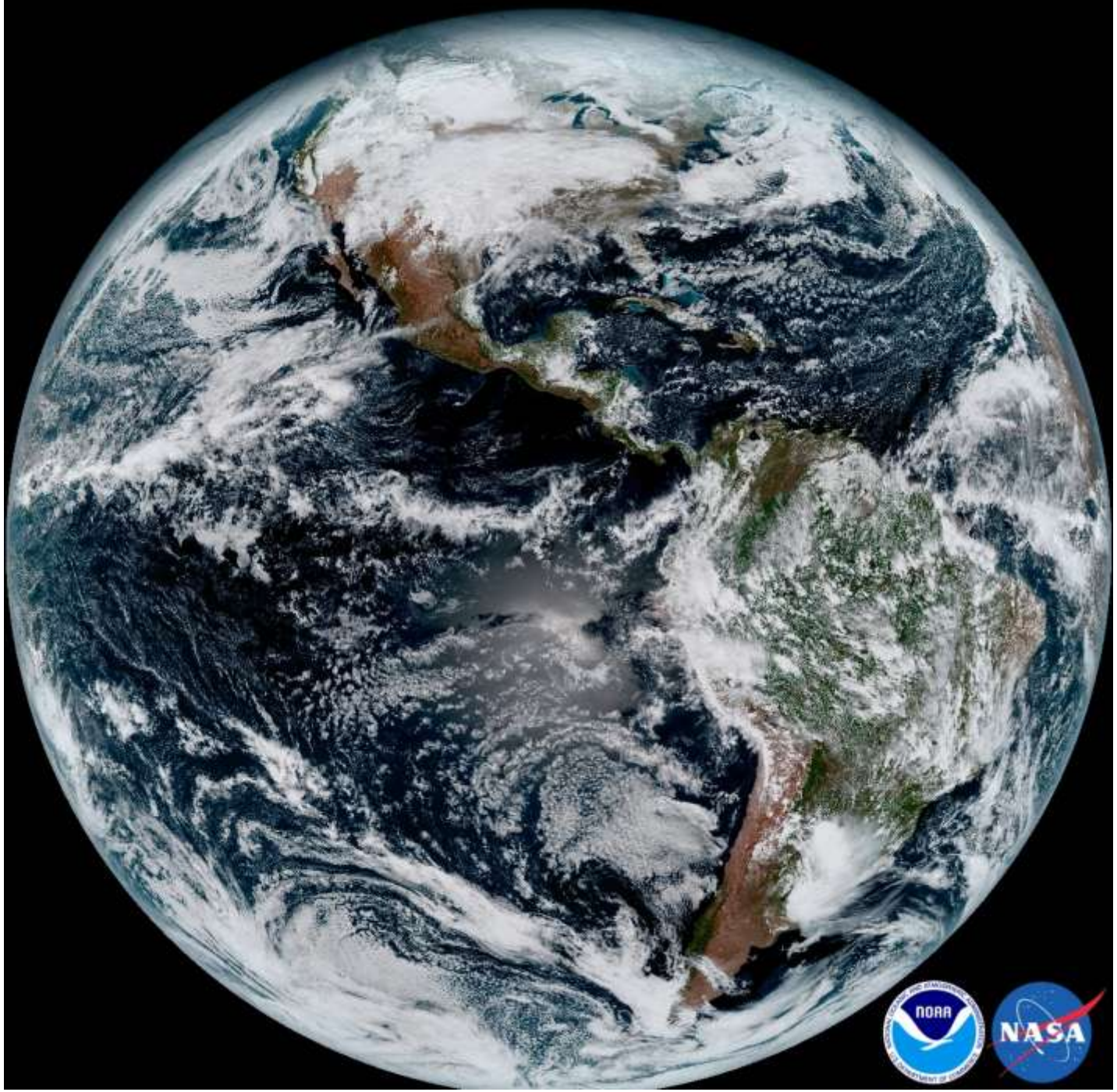
ESA, EUMETSAT, and the European space industry launched the MSG-4 geostationary satellite 15 July 2015.



Next Generation: The Geostationary Operational Environmental Satellite – R Series (GOES-R) will have advanced spacecraft and instrument technology that will provide more timely and accurate weather forecasts.

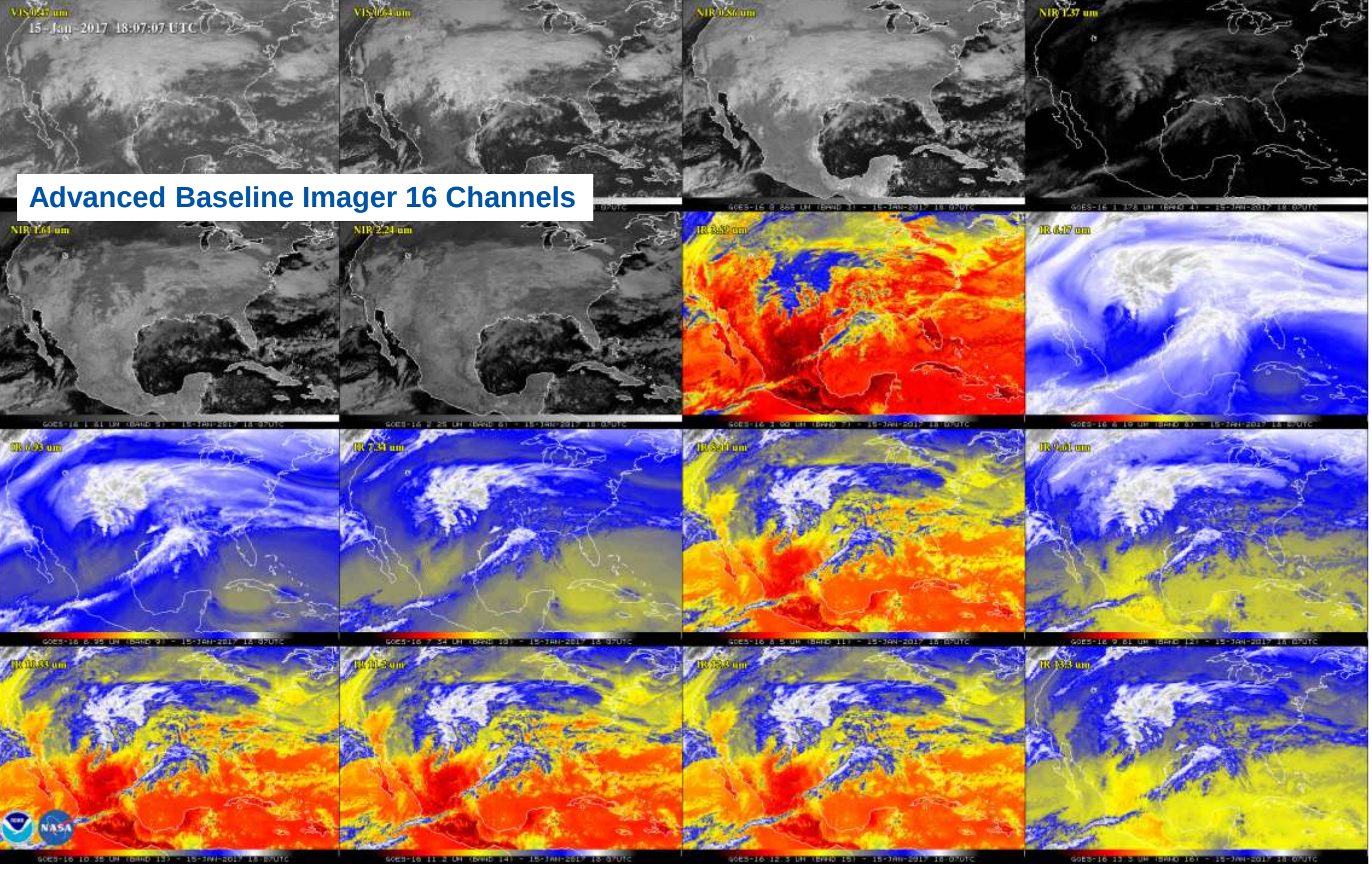
Launched in 19 Nov. 2016





GOES-16 color image

Scans hemisphere every 15 minutes
Can scan at up to 30 sec intervals for continental U.S.



2 VIS
4 NIR
10 TIR

Lightning Sensor on GOES 16