

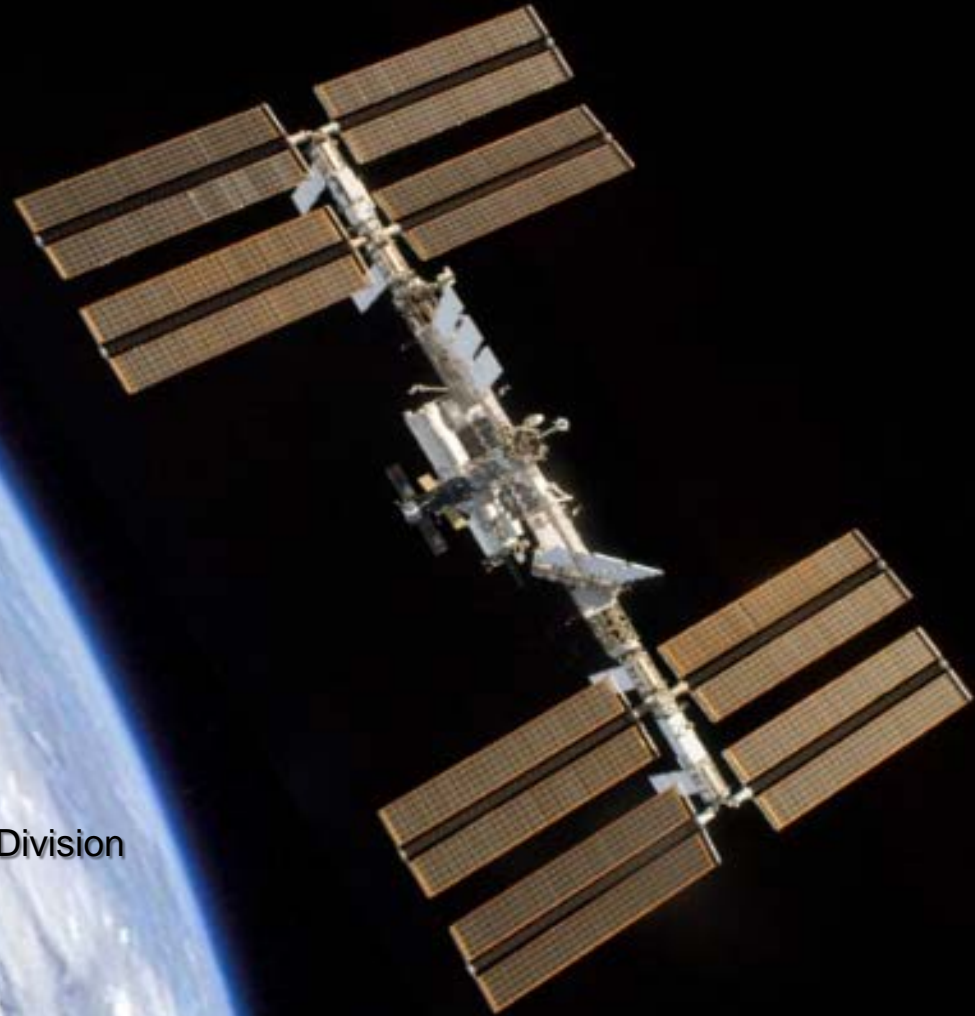


# *Remote Sensing From The International Space Station*

**Dr. William L. Stefanov**

Assoc. ISS Program Scientist for Earth Observations,  
and Astromaterials Research and Exploration Science Division  
NASA Johnson Space Center, Houston, Texas, USA

[william.l.stefanov@nasa.gov](mailto:william.l.stefanov@nasa.gov)





# Remote sensing of Earth: Why ISS?

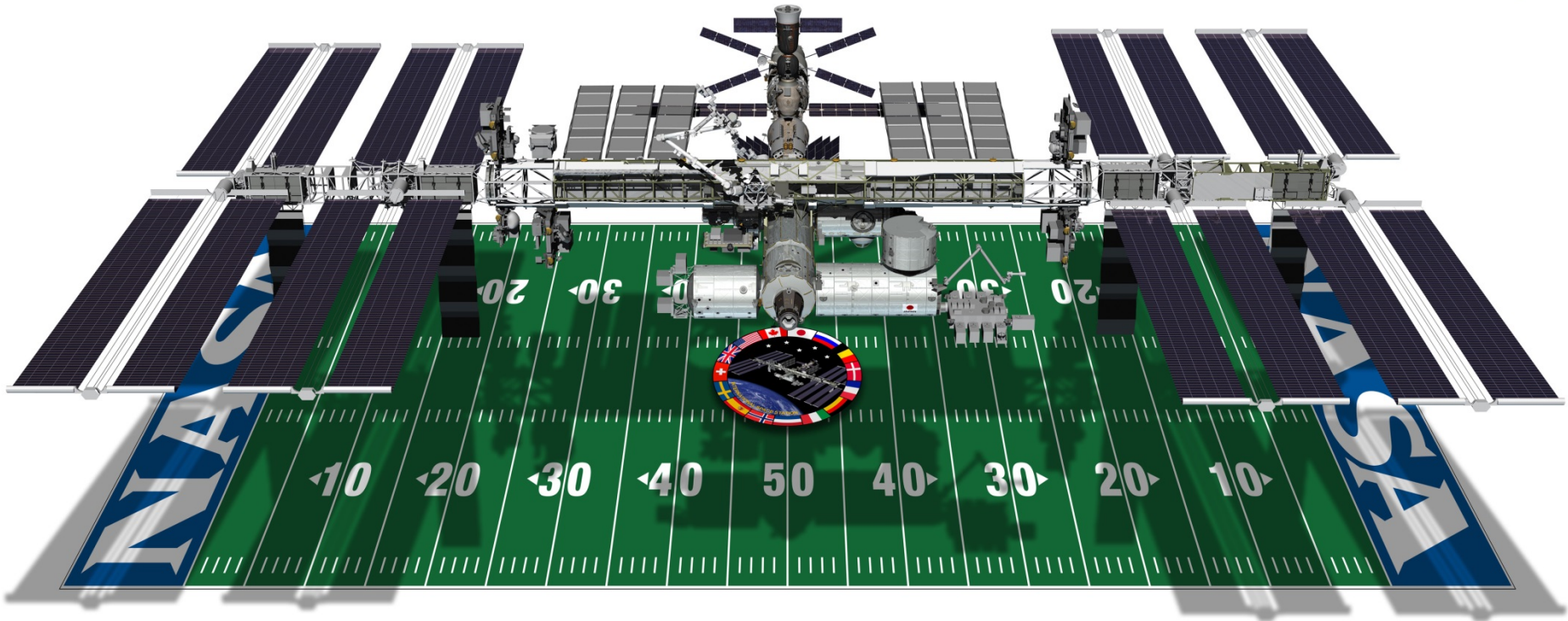


## **Polar orbit**

- Sun-synchronous – designed for long term repeatability of data
- Typically nadir viewing, crosses every point on Earth ~ 12-14 days near local solar noon/local midnight
- Landsat series collecting data since 1972
- Pointing capability, satellite constellations

## **Inclined Equatorial Orbit: ISS**

- Sun-asynchronous – similar illumination 3-4 days every 90 days
- Nadir to highly oblique imagery possible from hand-held cameras, WOLF, external sensors
- Provides opportunity to collect unique datasets for scientific study, disaster response
- Data is complementary to polar-orbiting satellite data
- Opportunity for instrument cross-calibration

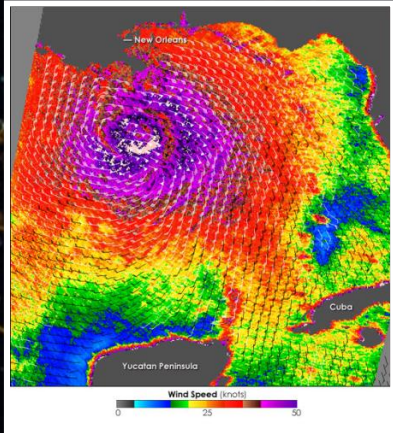


[www.nasa.gov](http://www.nasa.gov)

- Inclined equatorial orbit covers Earth from ~ 52 degrees N/S
- 240 statute miles (386.24 km) average altitude
- 17,500 mph (32, 410 km/hour)
- Approximately 16 orbits each day; crew sees 16 sunrises/sunsets
- Module Length: 167.3 feet (51 meters)
- Truss Length: 357.5 feet (109 meters)
- Solar Array Length: 239.4 feet (73 meters)
- Mass: 924,739 pounds (419,455 kilograms)
- Habitable Volume: 13,696 cubic feet (388 cubic meters)
- Pressurized Volume: 32,333 cubic feet (916 cubic meters)
- Power Generation: 8 solar arrays = 84 kilowatts
- Lines of Computer Code: approximately 2.3 million



# Earth Science



- Platform with full services (power, data, thermal) in LEO (~400 km)
  - All geographic locations between 51.6 North and South latitude
  - 85% of the Earth's surface
  - 95% of the world's populated landmass every 1-3 days
  - External sites for nadir, zenith, ram and wake
  - Variable (and precessing) lighting (changes with subsequent passes)
  - Well-suited for test bed concepts with hardware change out and upgrades

# SPONSORSHIP

## Funding Sources



For more information on research sponsorship and funding, see:

[http://www.nasa.gov/mission\\_pages/station/research/funding\\_information.html](http://www.nasa.gov/mission_pages/station/research/funding_information.html)

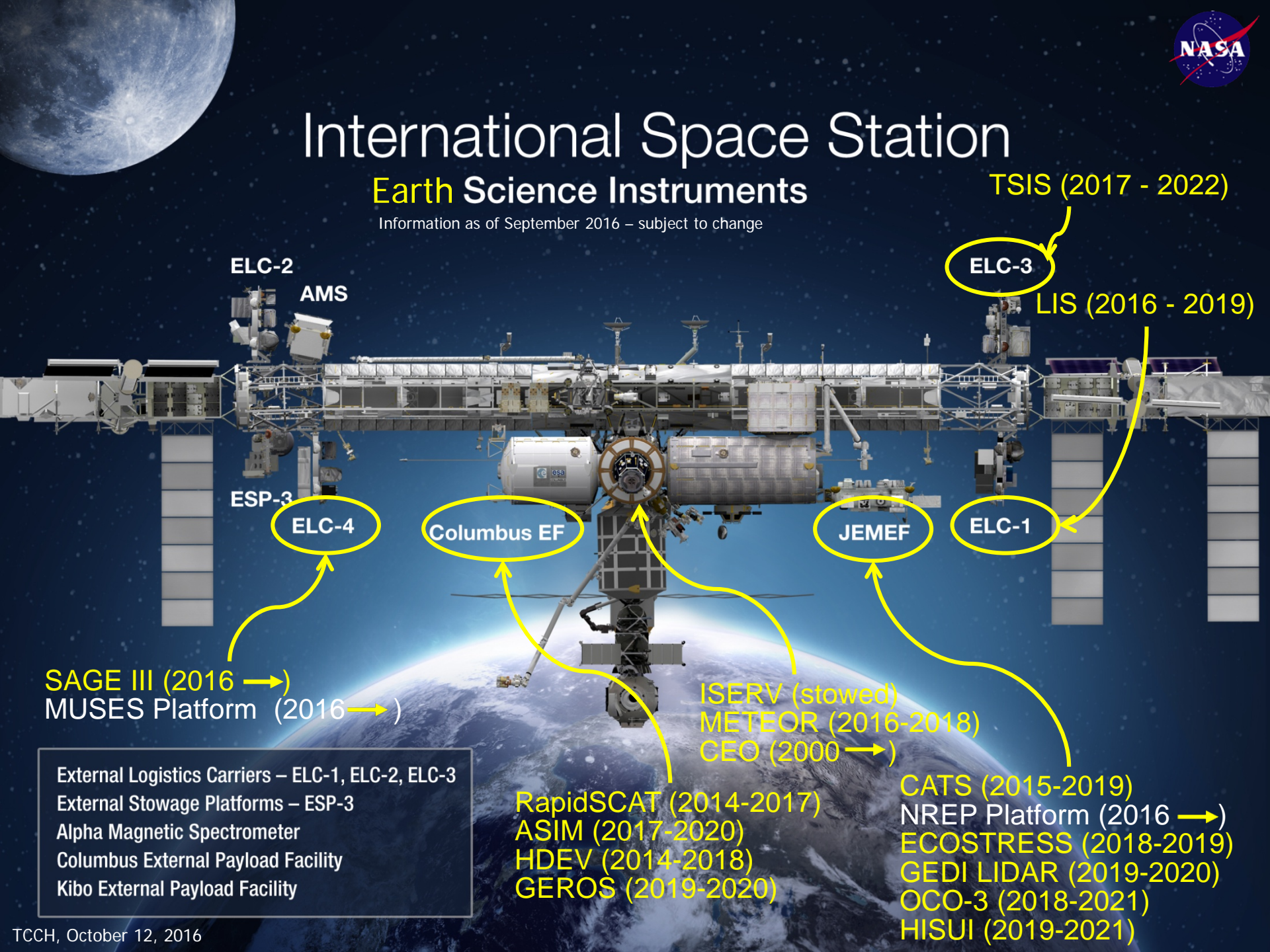




# International Space Station

## Earth Science Instruments

Information as of September 2016 – subject to change



TSIS (2017 - 2022)

ELC-3

LIS (2016 - 2019)

ELC-2

AMS

ESP-3

ELC-4

Columbus EF

JEMEF

ELC-1

SAGE III (2016 →)

MUSES Platform (2016 →)

ISERV (stowed)

METEOR (2016-2018)

CEO (2000 →)

RapidSCAT (2014-2017)

ASIM (2017-2020)

HDEV (2014-2018)

GEROS (2019-2020)

CATS (2015-2019)

NREP Platform (2016 →)

ECOSTRESS (2018-2019)

GEDI LIDAR (2019-2020)

OCO-3 (2018-2021)

HISUI (2019-2021)

External Logistics Carriers – ELC-1, ELC-2, ELC-3

External Stowage Platforms – ESP-3

Alpha Magnetic Spectrometer

Columbus External Payload Facility

Kibo External Payload Facility



# Crew Earth Observations Facility

**Sensor:** Crew Earth Observations (CEO)

**Location:** internal, Station windows

**Sponsor/Funding:** ISSP

**Prime Mission:** collection of Earth imagery in support of disaster response, and dynamic events with other ISS sensor systems. Also supports education/outreach and focused short-term science objectives.

**ISS Timeframe:** 2000-2024

**Principal Investigator:** William L. Stefanov, JSC

**Pointing capability:** variable, dependant on window and lens

**Geometric resolution:** variable, depends on lens  
< 3 m/pixel with 1000 mm lens to > 30 m/pixel with 110 mm and shorter lenses

**Spectral sensitivity:** visible RGB, poorly constrained bandpass (potential for NIR imagery using modified camera)

**Scene Size:** variable, depends on lens, ISS altitude

**Data take to availability time:** ~ 24 hours for full resolution data, may be possible to expedite

**Data availability:** Public; <https://eol.jsc.nasa.gov>



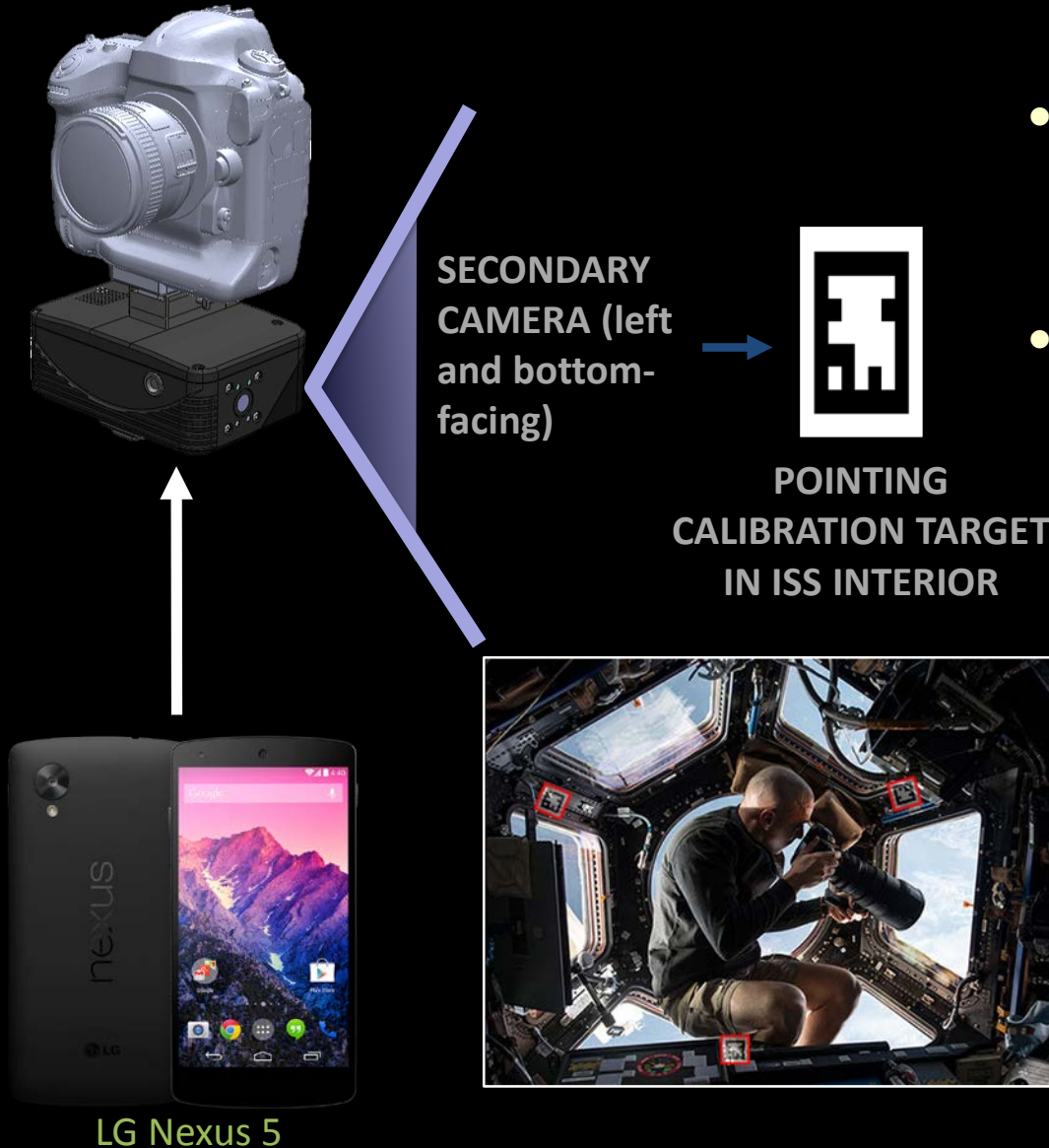




# GeoCam Space System – early 2017



## GeoSens Hardware



- Pointing Calibration Targets mounted in cupola
  - Ideally, semi-permanent mounting to avoid recurring setup time
- During photography, ensure some calibration target is occasionally in view of secondary camera
  - (Example: In view for at least 1 second every 5 minutes)
  - Given proper target placement, this may happen without explicit astronaut attention
  - Sensor package can use an audible tone to indicate rare cases when astronaut attention is needed
  - Trade-off: More targets vs. higher chance calibration activity is needed



# Meteor Composition Determination (METEOR)

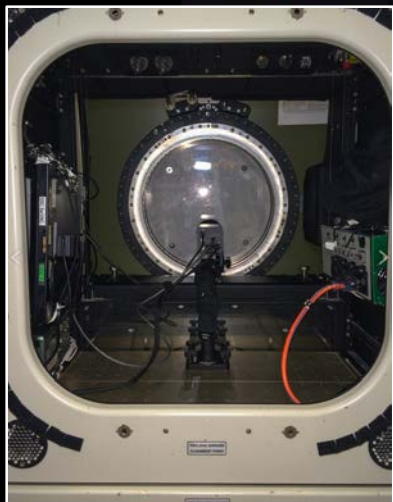
**Description:** Meteor's mission objective is to fly a visible spectroscopy instrument to the ISS for the primary purpose of observing meteors in Earth orbit. Meteor uses image analysis to provide information on the physical and chemical properties of the meteoroid dust, such as size, density, and chemical composition. Meteor plans to operate for 2 years (as allowed by science priorities) in the WORF volume.

## Payload Description:

- High-resolution video and still images of atmosphere with software triggering for bright "events"
- Camera system collects information in visible wavelengths (up to 700 nm) for spectral analysis of Fe, Ca, Mg, Na emission lines
- Mounted in Window Observational Research Facility (WORF)

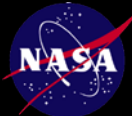
## Research Overview:

- Meteors cross the field of view of the observer's instrument and are recorded either photographically or electronically. Spectral measurements are made by a spectrograph, which records all wavelengths instantaneously.
- Investigators can then determine elemental abundances and temperatures by comparing known synthetic spectra to observed spectra.
- Meteor provides a continuous monitor of meteor interaction with the Earth's atmosphere without limitations of the ozone absorption.
- The resultant data aims to record the first measurement of meteor flux and allows for monitoring of carbon-based compounds. Investigation of meteor elemental composition is important to our understanding of how the planets developed.



Meteor observation over Colombia, July 11, 2016

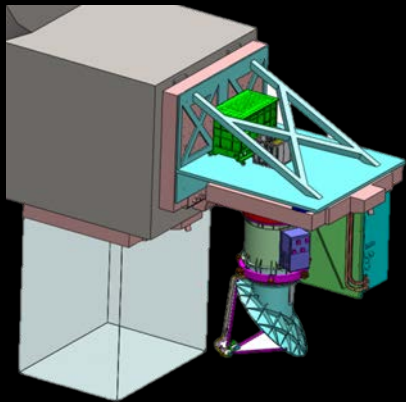
# RapidScat on ISS



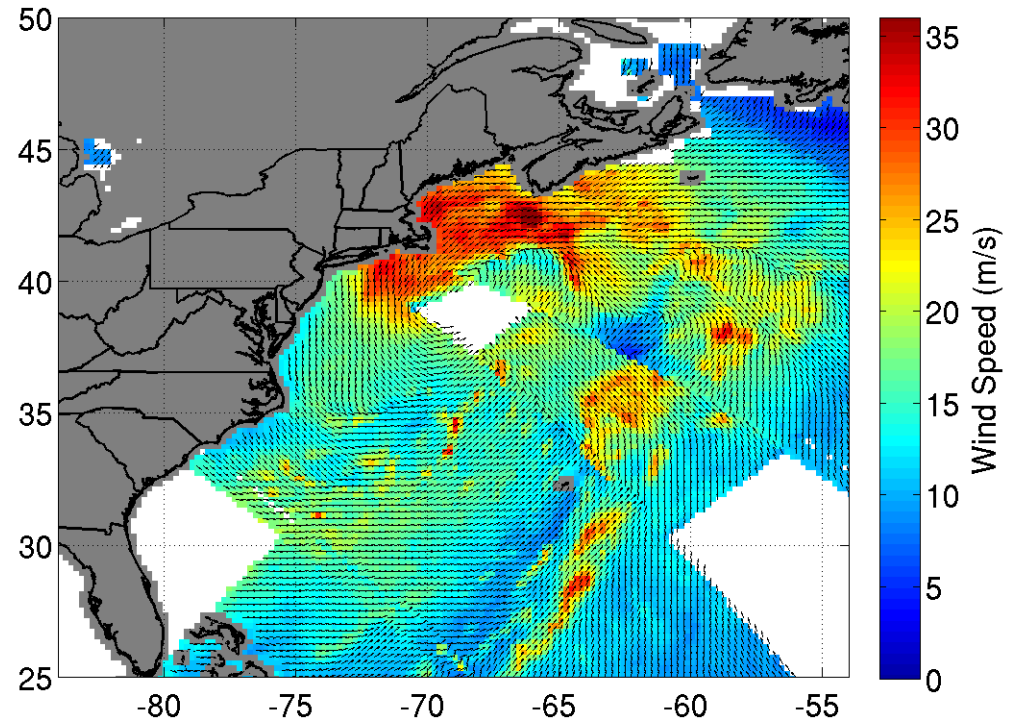
**Description:** Fly a radar scatterometer to continue ocean vector winds (OVW) measurements and to sample at all times of day enabled by ISS orbits (in contrast to twice a day sampling of sun-synchronous polar orbits) to observe diurnal variability of ocean winds and sea surface interaction not observable before

## Objectives:

- Continue more than 10-year Ku-band based vector winds observations
- Investigate the global diurnal cycle and remove the diurnal effect on scatterometer-based ocean vector winds
- Improve cross-calibration of and provide additional measurements to the international OVW constellation



RapidScat Juno UTC 27-Jan-2015 01:59:29 to 27-Jan-2015 11:15:13



Source: <http://cdn.phys.org/newman/gfx/news/hires/2015/1-nasameasured.png>

**Payload:** Refurbished SeaWinds EM scatterometer hardware with modification/augmentation to meet ISS payload accommodation and operation requirements and certified for flight and operations

- H-pol and V-pol pencil beams looking at about 45° from nadir, scanning at about 18 rpm with 0.75 m (D) reflector
- 800-1000 km swath, covering within  $\pm 52^\circ$  latitude in 48 hrs;  $\sim 1$  km ground-range resolution
- Wind resolution comparable to QuikSCAT
- Mass: 200 kg, Power: 250 W; Data Rate: 40 kbps, continuous

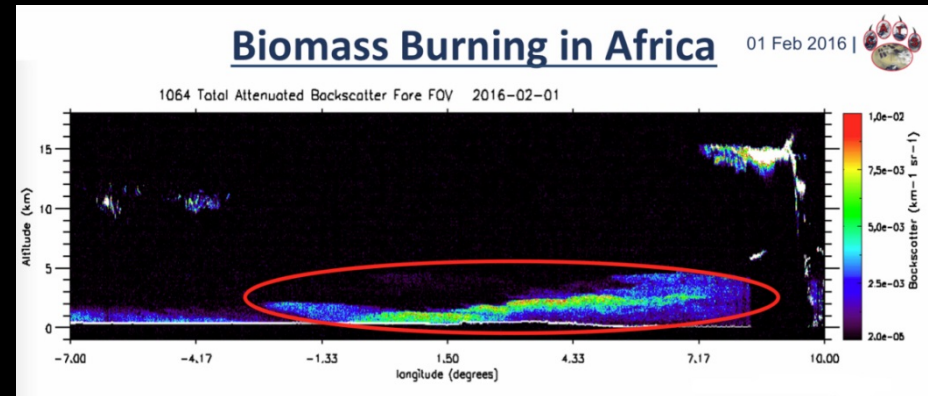


# Cloud-Aerosol Transport System (CATS)

## Key Science Objectives

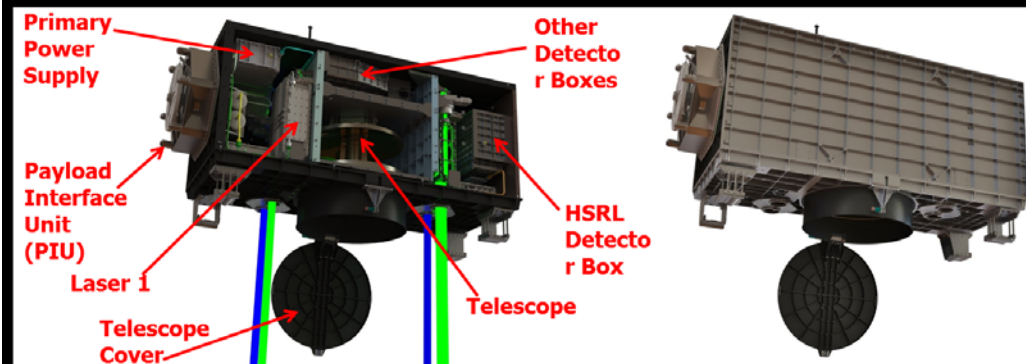
- Demonstrate multi-wavelength aerosol and cloud retrievals.
- Provide cloud and aerosol data to help bridge the gap between CALIPSO and future missions.
- Enable aerosol transport models with near real-time data downlink from ISS
- The ability of an aerosol plume to transport long distances is determined by its injection height relative to the local planetary boundary layer (PBL).
- Passive aerosol measurements from space provide valuable constraints on column aerosol loading.
- However, models lack observational constraints on vertical distribution.
- ISS orbit is intriguing for tracking of plumes and study of diurnal effects (something not possible with A-Train orbit).

Mode 1 ground resolution: ~ 7km  
 Mode 2, 3 ground resolution: ~14 m



- **CATS employs 2 high repetition rate lasers**
  - One operates at 532, 1064 nm
  - Second is seeded to provide narrow linewidth for HSRL measurements and frequency-tripled for use at 355 nm
- **CATS has a 60 cm beryllium telescope with narrow field-of-view (FOV)**
  - 4 instantaneous fields of view (IFOV)

Laser 1 Type	Nd: YVO <sub>4</sub>
Laser 1 Wavelengths	532, 1064 nm
Laser 1 Rep. Rate	5000 Hz
Laser 1 Output Energy	~1 mJ/pulse
Laser 2 Type	Nd: YVO <sub>4</sub> , seeded
Laser 2 Wavelengths	355, 532, 1064 nm
Laser 2 Rep. Rate	4000 Hz
Laser 2 Output Energy	~2 mJ/pulse
Telescope Diameter	60 cm
View Angle	0.5 degrees
Telescope FOV	110 microradians

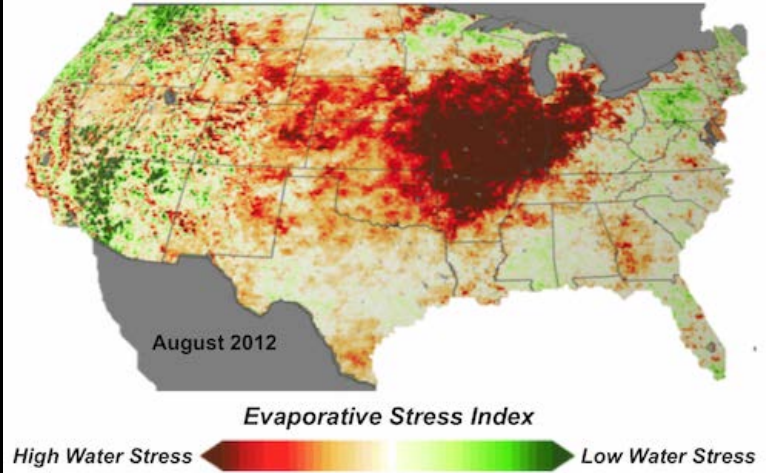


# ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

**Description:** Multispectral thermal infrared sensor mounted on JEM-EF to measure the brightness temperature of plants, and use that information to better understand how much water plants need and how they respond to stress (evapotranspiration dynamics).

Parameter	Science Requirement at 400 km	Expected Instrument Capability at 400 km
Ground Sample Distance (m) Crosstrack x Downtrack at nadir	≤ 100 x ≤100	≤69 x ≤38
Swath width (ISS nominal altitude range is 385 to 415 km)	≥360	400
Wavelength range (μm)	8-12.5	8-12.5
Number of bands	≥3	≥5
Radiometric accuracy (K@300K)	≤1	≤0.5
Radiometric precision (K@300K)	≤0.3	≤0.15
Dynamic Range (K)	270-335	200-500
Data collection	CONUS, twelve 1,000 x1,000 km key climate zone and twenty-five Fluxnet sites for all opportunities. On average 1 hour of science data per day	≥1.5 hours per day of science data

*Water Stress Threatens Ecosystems Productivity*



**Science Questions:**

- How is the terrestrial biosphere responding to changes in water availability?
- How do changes in diurnal vegetation water stress impact the global carbon cycle?
- Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improved drought estimation?

**Science Objectives:**

- Identify critical thresholds of water use and water stress in key climate sensitive biomes (e.g., tropical/dry transition forests, boreal forests);
- Detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the diurnal cycle;
- Measure agricultural water consumptive use over CONUS at spatiotemporal scales applicable to improving drought estimation accuracy.



# Global Ecosystem Dynamics Investigation Lidar (GEDI)

**Description:** Active sensor system 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. GEDI will provide the first global, high resolution observations of forest vertical structure.

## Payload Description:

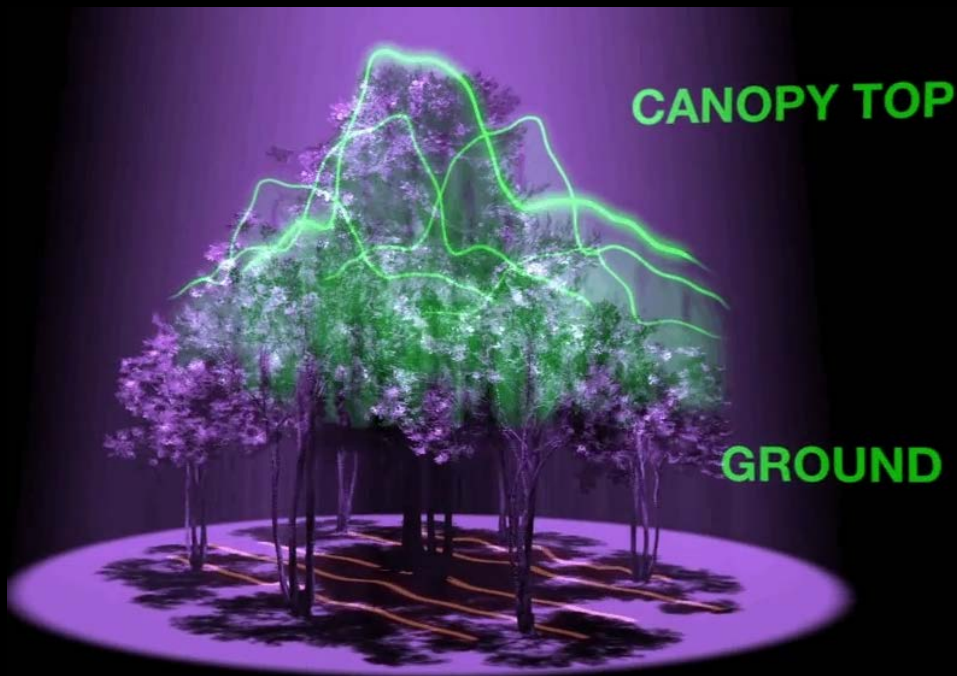
- Nominal one-year mission, will collect > 16 billion vertical profile waveform observations
- 3 laser system to produce 14 parallel track measurements with 25 m footprints, used to model aboveground biomass <500m spatial resolution
- Mounted on Japanese Experiment Module Exposed Facility

## Science Questions:

- What is the aboveground carbon balance of the land surface?
- What role will the land surface play in mitigating atmospheric CO<sub>2</sub> in the coming decades?
- How does ecosystem structure affect habitat quality and biodiversity?

## Science Objectives:

- Quantify the distribution of above-ground carbon at fine spatial resolution
- Quantify changes in carbon resulting from disturbance and subsequent recovery
- Quantify the spatial and temporal distribution of forest structure and its relationship to habitat quality and biodiversity
- Quantify the sequestration potential of forests through time under changing land use and climate.



# Total and Spectral Solar Irradiance Sensor (TSIS)

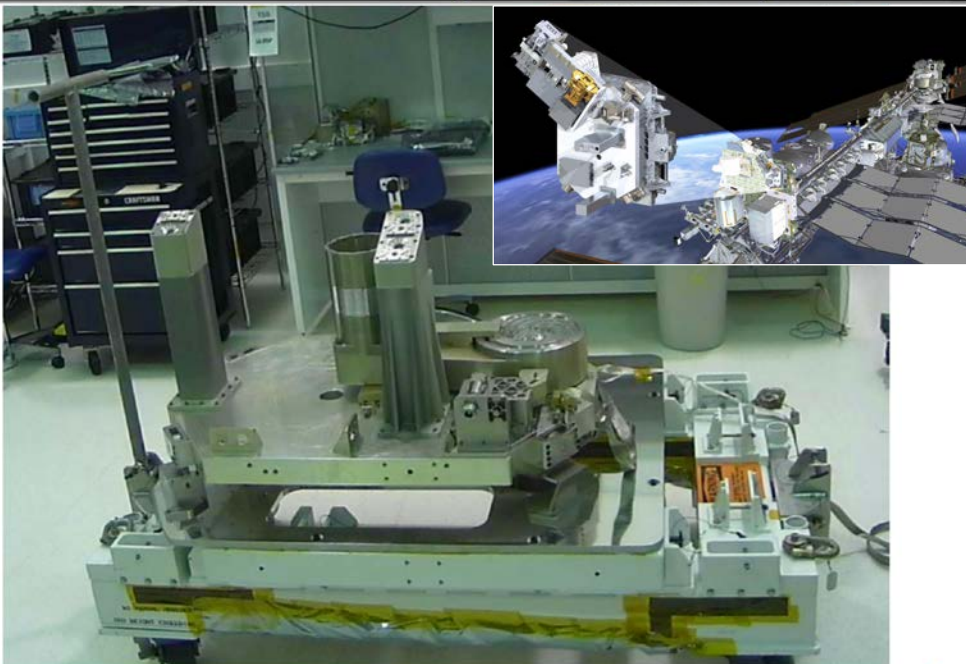
## Description: Mounted on the ExPRESS

Logistics Carrier 3 (ELC-3), TSIS will acquire measurements of total and spectral solar irradiance (TSI and SSI, respectively). TSI is required for establishing Earth's total energy input while SSI is needed to understand how the atmosphere responds to changes in the sun's output. Solar irradiance is one of the longest and most fundamental of all climate data records derived from space-based observations.

## Payload Description:

- Dual-instrument package of Total Irradiance Monitor (TIM) and Spectral Irradiance Monitor (SIM), both heritage instruments from NASA Solar Radiation and Climate Experiment (SORCE)
- TIM measures TSI incident at outer boundaries of atmosphere
- SIM measures SSI from 200 – 2400 nm (96% of TSI)

## TSIS Main Baseplate Assembly



## Science Objectives:

- Nominal five-year mission, provides continuation of TSI record from SORCE and USAF STPSat-3
- Quantify variability in incoming solar radiation, as the most precise indicator for changes in Sun's energy output
- Determine regions/layers of Earth's atmosphere that are affected by solar variability, in order to quantify solar forcing mechanisms causing changes in climate
- Determination of whether the Sun's spectral ultraviolet output is in- or out-of-phase with visible wavelength output
- Provision of TSI and SSI data to support community science in climate, atmosphere, solar physics, and radiative transfer modeling



# DLR Earth Sensing Imaging Spectrometer (DESI)

**Description:** Commercial hyperspectral instrument to be installed on the Teledyne-Brown Engineering Multi-User System for Earth Sensing (MUSES) platform for ISS. The instrument is being built by DLR (Deutsches Zentrum für Luft- und Raumfahrt e.V.; German Aerospace Center).

Details of the final sensor configuration and commercial user data pricing structure are still being finalized.



<b>Lens objective</b>	F# = 4 / f = 100mm (telecentric)
<b>FOV / swath</b>	7.6° / 44km/57km
<b>IFOV / GSD</b>	0.0074° / 79m/104m
<b>Spectral range</b>	450nm – 950nm (400 - 1000nm)
<b>Spectral sampling</b>	≈ 2,32nm
<b>Spectral channels</b>	240 (without binning)
<b>Polarization sensitivity</b>	≤ 0,3%
<b>Size</b>	430 mm × 190 mm × 135 mm
<b>In orbit calibration</b>	2 internal lamps, LED screen
<b>Pointing (along-track)</b>	± 15°

**Example Markets/Research Areas:**

- Agriculture
- Atmospheric Studies
- Maritime Awareness
- Surface Mineralogy and Resource Assessment
- Forestry
- Ocean Studies
- Urban Ecology, Climatology, and Planning
- Water Quality Studies



International Disaster  
Charter  
**EARTH SCIENCE &  
REMOTE SENSING UNIT**  
AREA

**Regional Remote  
Sensing**  
Studies on climate change  
around the Houston area

**Benefits to Humanity**  
How research on the  
International Space Station  
benefits all

**Science Toolbox**  
Resources on Earth  
Science and Remote  
Sensing topics

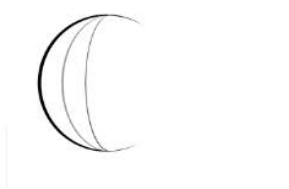
**Publications**  
Publications written by  
scientists on various Earth  
Science topics

**14 Tools**  
Allows you to search  
multiple Earth-viewing  
sensors in one location



[SENSORS](#)   [ESRS IN THE NEWS](#)   [14 SEARCH TOOL](#)   [PUBLICATIONS](#)   [REGIONAL RS](#)   [ESRS TEAM](#)

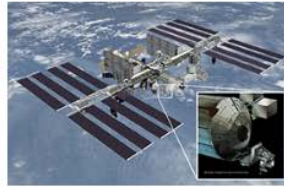
### Current NASA Missions on ISS



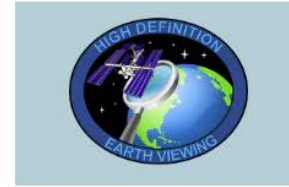
**CEO**  
Crew Earth Observations



**CATS**  
Cloud Aerosol Transport System



**Rapid Scat**  
Rapid Scatterometer



**HDEV**  
High Definition Earth-Viewing experiment



**Tropical Cyclone**  
The Cyclone Intensity Measurements from  
the ISS



**EarthKAM**  
Sally Ride Earth Knowledge Acquired by  
Middle School Students



**RAIDS**  
Remote Atmospheric and Ionospheric  
Detection System



**Meteor**  
Meteor Composition Determination



**All Missions**  
Past, present, and future NASA, National  
Lab, and International Partner missions