Earth Science Research on the International Space Station

Committee on Earth Science and Applications from Space (CESAS)
Space Studies Board
National Academies of Science, Engineering, Medicine
29 March 2016

Julie A. Robinson, Ph.D., Chief Scientist, International Space Station
Julie.a.robinson@nasa.gov

William L. Stefanov, Ph.D., Associate ISS Program Scientist for Earth Observations and Astromaterials Research and Exploration Science Division
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, WORF, 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
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, two commercially developed platforms (NREP and MUSES) provided services for short-term testing of instrument, and include opportunities for NASA and non-NASA access
Applications of Remote Sensing from ISS

- Climate Science
- Geologic Mapping
- Economic Resource Assessment
- Hazard Assessment
- Land Cover Mapping/Change
- Geomorphology/Landscape Characterization
- Soil Mapping
- Hydrology
- Climatology/Surface Fluxes
- Environmental Monitoring
## Working Plan

Multi-Increment Payload Resupply and Outfitting Model (MiPROM), as of 18 December 2015

**NOTE:** This is a strategic plan and subject to change.

### Payload Readiness Date

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2017-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2018-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2019-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2020-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2021-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2022-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2023-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
<tr>
<td>2024-1</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
<td>April 15</td>
</tr>
</tbody>
</table>

### Candidate Sites

<table>
<thead>
<tr>
<th>Center</th>
<th>Site Number</th>
<th>Payload</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELC 1</td>
<td>3</td>
<td>P3</td>
<td>2015-1</td>
</tr>
<tr>
<td>ELC 2</td>
<td>8</td>
<td>S3 Lower</td>
<td>2016-1</td>
</tr>
<tr>
<td>ELC 3</td>
<td>3</td>
<td>S3 Upper</td>
<td>2017-1</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>S3 Upper</td>
<td>2018-1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>P3 Upper</td>
<td>2019-1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>EPF BZ</td>
<td>2020-1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>EPF SDO</td>
<td>2021-1</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>EPF SDS</td>
<td>2022-1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>EPF SDN</td>
<td>2023-1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>EPF SDO</td>
<td>2024-1</td>
</tr>
</tbody>
</table>

### Legend

- **NASA payloads** = no shading
- **JAXA payloads** = orange
- **ESA payloads** = purple
- **Candidate payloads** = gray
- **Potential vacant sites** = green

---

**Temp storage location**

---

**NASA launch; ESA ops**
# Working Unpressurized Launch Manifest as of March 2016

**(Subject to change)**

## Earth Science

<table>
<thead>
<tr>
<th>SpX-8</th>
<th>Ascent</th>
<th>Descent</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpX-8</td>
<td>BEAM</td>
<td></td>
</tr>
<tr>
<td>SpX-9*</td>
<td>IDA #2</td>
<td></td>
</tr>
<tr>
<td>SpX-10*</td>
<td>STP-H5 <em>(LIS)</em></td>
<td>SAGE NVP</td>
</tr>
<tr>
<td>SpX-11*</td>
<td>ROSA</td>
<td>MUSES Multi-user platform</td>
</tr>
<tr>
<td>SpX-12*</td>
<td>CREAM</td>
<td></td>
</tr>
<tr>
<td>SpX-13*</td>
<td>ASIM</td>
<td>ACES</td>
</tr>
<tr>
<td>SpX-14*</td>
<td>IDA #3</td>
<td></td>
</tr>
<tr>
<td>SpX-15*</td>
<td>TSIS</td>
<td>MISSE-FF</td>
</tr>
<tr>
<td>SpX-16*</td>
<td>ECOSTRESS (EF)</td>
<td>RRM3 (FRAM 2) TBR</td>
</tr>
<tr>
<td>SpX-17*</td>
<td>OCO-3 (EF)</td>
<td>STP-H6</td>
</tr>
<tr>
<td>SpX-18*</td>
<td>GEDI (EF)</td>
<td><em>(not available)</em></td>
</tr>
<tr>
<td>SpX-19*</td>
<td><em>(Systems Placeholder)</em></td>
<td></td>
</tr>
<tr>
<td>SpX-20*</td>
<td>NASA-TBD-NL (EF) TBR</td>
<td>GEROS</td>
</tr>
</tbody>
</table>

**Key:**
- normal = NASA research
- bold = NL
- purple = ESA
- orange = JAXA
ISS Extension to at least 2024

• Obama Administration committed in 2014 to extend space station operations to at least 2024
• 2015, Congress authorized this extension
• ISS International Partners Japan, Canada and Russia have since announced their support for this extension. ESA (the European Space Agency) is currently working an extension through their Ministerial process.
• Adding four years from 2020-2024 nearly doubled the opportunity for hosting instruments on ISS
• We are not beginning decommissioning and the ISS engineering life is at least 2028
Guide to Earth Observation on ISS


Existing facilities and instruments:
ISS Research & Technology
http://www.nasa.gov/iss-science/

@ISS_Research

ISS Research Blog “A Lab Aloft”
http://go.usa.gov/atI

Space Station Research Explorer App for Apple and Android

- iPad
- Android
EXTERNAL INSTRUMENTS
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

**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 ±52° latitude in 48 hrs
- Wind resolution comparable to QuikSCAT
- Mass: 200 kg, Power: 250 W; Data Rate: 40 kbps, continuous

The ISS RapidScat instrument consists of legacy SeaWinds Engineering Model hardware plus new power and digital interface and new antenna (0.75 m diameter).
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).

Biomass Burning in Africa

ISS orbit. The low-inclination orbit permits extensive measurements over aerosol source and aerosol transport regions.
CATS Instrument

- **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)

<table>
<thead>
<tr>
<th>Laser 1 Type</th>
<th>Nd: YVO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser 1 Wavelengths</td>
<td>532, 1064 nm</td>
</tr>
<tr>
<td>Laser 1 Rep. Rate</td>
<td>5000 Hz</td>
</tr>
<tr>
<td>Laser 1 Output Energy</td>
<td>~1 mJ/pulse</td>
</tr>
<tr>
<td>Laser 2 Type</td>
<td>Nd: YVO₄, seeded</td>
</tr>
<tr>
<td>Laser 2 Wavelengths</td>
<td>355, 532, 1064 nm</td>
</tr>
<tr>
<td>Laser 2 Rep. Rate</td>
<td>4000 Hz</td>
</tr>
<tr>
<td>Laser 2 Output Energy</td>
<td>~2 mJ/pulse</td>
</tr>
<tr>
<td>Telescope Diameter</td>
<td>60 cm</td>
</tr>
<tr>
<td>View Angle</td>
<td>0.5 degrees</td>
</tr>
<tr>
<td>Telescope FOV</td>
<td>110 microradians</td>
</tr>
</tbody>
</table>
DLR Earth Sensing Imaging Spectrometer (DESIS) on the MUSES Platform

**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. NASA will receive a yet to be determined “credit value” for data takes, nominally distributed over the lifetime of the sensor. The licensing agreement for use and distribution of NASA data to science investigators is likewise still in discussion.

**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

**Specifications:**

- **Lens objective**
  - F# = 4 / f = 100mm (telecentric)
- **FOV / swath**
  - 7.6° / 44km/57km
- **IFOV / GSD**
  - 0.0074° / 79m/104m
- **Spectral range**
  - 450nm – 950nm (400 - 1000nm)
- **Spectral sampling**
  - ≈ 2.32nm
- **Spectral channels**
  - 240 (without binning)
- **Polarization sensitivity**
  - ≤ 0.3%
- **Size**
  - 430 mm × 190 mm × 135 mm
- **In orbit calibration**
  - 2 internal lamps, LED screen
- **Pointing (along-track)**
  - ± 15°

**Primary Science Objective:**
Monitor the vertical distribution of aerosols, ozone and other trace gases in Earth’s stratosphere and troposphere to enhance understanding of ozone recovery and climate change processes in the upper atmosphere.

**Mission Implementation**

| Partners       | LaRC  
|                | JSC/ISSP  
|                | ESA     
| Risk           | NPR 7120.5D/NM7120.81 Category 3 / NPR 8705.4 Payload Risk Class C  
| Launch         | 2016    
| Orbit          | ISS Mid-Inclination orbit  
| Life           | 3 years (nominal) / ISS manifest through 2024 for extended mission  
| Payload        | Sensor Assembly (LaRC), Hexapod (ESA), CMP (LaRC), ExPA (JSC/ISS), ICE (LaRC), HEU (ESA), IAM (LaRC), DMP (LaRC) Nadir Viewing Platform (LaRC)  
| Mass & Power   | 540 W (CBE, mix between 120Vdc and 28 Vdc)  
|                | 460 kg (CBE)  

SAGE III on ISS directly supports NASA Strategic Goals to extend and sustain human activities across the solar system; expand scientific understanding of the Earth and the universe in which we live.
SAGE Science Results & Objectives

• SAGE produces vertical profiles of aerosols and gases in the stratosphere and upper troposphere
• The multi-decadal SAGE ozone and aerosol data sets have undergone intense scrutiny and are the international standard for accuracy and stability
• SAGE data has been used to monitor the effectiveness of the Montreal Protocol (January 1989)
Orbiting Carbon Observatory (OCO-3) Project Overview

Primary Science Objectives

- Collect the space-based measurements needed to quantify variations in the column averaged atmospheric carbon dioxide (CO₂) dry air mole fraction, $X_{CO2}$, with the precision, resolution, and coverage needed to improve our understanding of surface CO₂ sources and sinks (fluxes) on regional scales ($\geq 1000$ km).
- Measurement precision and accuracy requirements same as OCO-2
- Operation on ISS allows latitudinal coverage from 51 deg S to 51 deg N

**Major Features:**
- Category 3 mission per NPR 7120.5E
- Risk classification C per NPR 8705.4
- High-resolution, three-channel grating spectrometer (JPL)
- Partnership between SMD and HEOMD
- Deployed on the International Space Station
- Launch Readiness: TBD

**OCO-3 Requirements in Payload Interface Agreement**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>500 kg</td>
</tr>
<tr>
<td>Power</td>
<td>600 W</td>
</tr>
<tr>
<td>Data Rate</td>
<td>3 Mbps</td>
</tr>
<tr>
<td>Volume</td>
<td>1.85 m x 1.0 m x 0.8 m</td>
</tr>
<tr>
<td>Thermal</td>
<td>Fluid Cooling Loop</td>
</tr>
</tbody>
</table>
Lightning Imaging Sensor (LIS) on ISS

**Mission Overview**

- NASA developed and demonstrated space-based lightning observation as a remote sensing tool under Earth Observing System (EOS) and Tropical Rainfall Measuring Mission (TRMM) (*LIS still operational on TRMM*).
- LIS on the ISS will extend TRMM time series observations, expand latitudinal coverage, and provide real time observations in support of important and pressing science and applications objectives.
- Integrate as hosted payload on DoD Space Test Program (STP-H5)

**Measurement**

- LIS measures global lightning (*amount, rate, radiant energy*) during both day and night, with storm scale resolution, millisecond timing, and high, uniform detection efficiency.
  - LIS daytime detection is both unique and scientifically important (>70% occurs during day).
  - Only LIS globally detects TOTAL (*both cloud and ground*) lightning with no land-ocean bias.

**Science and Application Objectives**

- Lightning is quantitatively coupled to both thunderstorm and related geophysical processes.
- Therefore lightning observations provide important gap-filling inputs to pressing Earth system sciences issues in a wide range of disciplines (e.g., *weather, climate, atmospheric chemistry, lightning physics*).
- Real time observations will be provided to operational users.
- LIS data is the “Gold Standard” for global lightning climatology.
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)

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
**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).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Science Requirement at 400 km</th>
<th>Expected Instrument Capability at 400 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Sample Distance (m)</td>
<td>≤ 100 x ≤100</td>
<td>≤69 x ≤38</td>
</tr>
<tr>
<td>Crosstrack x Downtrack at nadir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swath width (ISS nominal altitude range is 385 to 415 km)</td>
<td>≥360</td>
<td>400</td>
</tr>
<tr>
<td>Wavelength range (µm)</td>
<td>8-12.5</td>
<td>8-12.5</td>
</tr>
<tr>
<td>Number of bands</td>
<td>≥3</td>
<td>≥5</td>
</tr>
<tr>
<td>Radiometric accuracy (K@300K)</td>
<td>≤1</td>
<td>≤0.5</td>
</tr>
<tr>
<td>Radiometric precision (K@300K)</td>
<td>≤0.3</td>
<td>≤0.15</td>
</tr>
<tr>
<td>Dynamic Range (K)</td>
<td>270-335</td>
<td>200-500</td>
</tr>
</tbody>
</table>

**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.

**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.
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
- 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 CO2 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.
**NASA Payloads - Crew Earth Observations**

| **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; [http://eol.jsc.nasa.gov](http://eol.jsc.nasa.gov)
Crew Earth Observations (CEO) – Upsala Glacier

2002
ISS004-E-6929 part

2009
ISS021-E-15242 part

2013, October 2
ISS037-E-5104 part

Slide courtesy of M.J. Wilkinson, Texas State University/JETS Contract, JSC
GeoCam Space System – late 2016/early 2017

GeoSens Hardware (NASA Ames)

- 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
GeoCam Space System – late 2016/early 2017

GeoRef Software (NASA Ames)

Reasonable rotation and geolocation to base image with only 3 tie points – developing fully automated geolocation
BACKUP

ISERV (stowed), Disaster Response Interfaces
Other USOS Sensor Systems & Capabilities relevant to Earth Science

**Internal**

- METEOR [2016] – visible spectrometer for observation of meteors in Earth orbit, WORF

**External**

- High Definition Earth Viewing (HDEV) [2014] – four-camera fixed system (fore, aft, and nadir) for collecting HD imagery of Earth and monitoring exposure degradation, Columbus EF

- NanoRacks External Platform (NREP) [2016] – pointable, stable platform for Earth-viewing instruments and technology tests, ELC. Four users of the platform were announced in August 2015:
  - Gumstix/Solar Cells (Yosemite Space) radiation effects on System on Chip (SoC) processors
  - Charge Injection Device (CID, Florida Institute of Technology) high contrast imaging technology test in low Earth orbit radiation
  - A-76 Technologies – test of preservation coatings and lubricants in the high stress space environment
  - Dependable Multiprocessing (DM7, Honeywell Aerospace/Morehead State University- DM7 processor test for CubeSat technology

- Multi-User System for Earth Viewing (MUSES) [2016] – pointable, stable platform for Earth-viewing instruments, ELC; additional capabilities beyond DESIS available

- Atmosphere-Space Interactions Monitor (ASIM) [2017] measure high altitude lightning that is discharged from thunderclouds, at altitudes of 90-100 km. These formations of lightning are known as "red sprites", "blue jets", and "elves" (ESA)

- GNSS Reflectometry, Radio Occultation and Scatterometry on ISS (GEROS-ISS) [2019] – sea surface roughness and wind speed from navigation satellite data (ESA)
Sensor: ISS SERVIR Environmental Research and Visualization System (ISERV) Pathfinder

Location: WORF, internal

Sponsor/Funding: NASA SERVIR, ISS National Lab

Prime Mission: Disaster analysis and support of humanitarian response; also agriculture, archeology, deforestation applications

ISS Timeframe: 2012 - 2015

Principal Investigator: Burgess Howell, MSFC

Pointing capability: 23 degrees along & cross-track

Geometric resolution: 2.8 meter nominal

Spectral sensitivity: visible to near-infrared wavelengths (0.35 – 0.80 μm)

Scene Size: 14.4 km x 9.6 km at 350 km altitude

Data take to availability time: ~ 3 hours nominal

Data availability: Public; short term storage at NSSTC/MSFC, long term archival storage TBD

ISERV system, including Canon EOS 7D camera body (not shown); Celestron 925 CPC telescope tube and 800 CPC pointing mount; and Hyperstar 3 lens
ISS SERVIR Environmental Research and Visualization System (ISERV) (Prime mission completed 2014, in stowage)

San Diego, California
Mulanje, Malawi
Nile River, Sudan
Lake Titicaca
Huntsville, Alabama
Grand Canyon
Andes Mts, Chile

Floods in Calgary, AB, June 22, 2013
Floods/Landslides, N. India, June 28, 2013
International Charter “Space and Major Disasters”

The International Charter aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through Authorized Users. Each member agency has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property.

Member Agencies:

Americas

Europe

Asia
Since late April/early May 2012, ISS has received 154 IDC activations; data collected for 43 events and delivered to USGS (ISSAC, CEO, HICO, ISERV)
Example of IDC targeting "nugget" delivered to NASA ISS sensor teams to aid in data collection.
USGS Hazards Data Distribution System

http://hddsexplorer.usgs.gov/
ISERV – Calgary Flood, June 2013

- 140 images taken to support mapping of flooded areas (red)
- Images given to Royal Canadian Mounted Police and other agencies for disaster response