NASA Earth Observations Resources

William L. Stefanov
Science Applications, Research and Development/ESCG
william.l.stefanov@nasa.gov

Cynthia A. Evans
ISS Program Science Office
cindy.evans-1@nasa.gov

Rajib Dasgupta
ISS National Laboratory Payloads Office
rajib.dasgupta-1@nasa.gov

NASA Johnson Space Center, Houston, TX USA
Introduction

• **ISS has significant utility as an Earth Remote sensing Instrument test bed.**
  • Remote Sensing is one of the major thrust areas for Utilization of ISS as a US National Laboratory

• **ISS Orbital Characteristics**

• **Window Observational Research Facility (WORF)**

• **Existing Earth Viewing Systems**
  **Pressurized**
  • International Space Station Agricultural Camera (ISSAC) – in WORF
  • Crew Earth Observations (CEO)
  **Unpressurized**
  • Hyper-spectral Imager for the Coastal Ocean (HICO)

• **Planned Earth Viewing Systems**
  **Pressurized**
  • ISS SERVIR Environmental Research and Visualization System (ISERV) – in WORF
  **Unpressurized**
  • Cloud Aerosol Transport System (CATS)
  • High Definition Earth Viewing (HDEV)
Sun-Synchronous Polar Orbits vs. Inclined Equatorial Orbits

**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
- Provides opportunity to collect unique datasets for scientific study, operational monitoring
- Data is complementary to polar-orbiting satellite data
Unlike polar-orbiting satellites such as Landsat or Terra, the International Space Station (ISS) has an inclined equatorial orbit that is not sun-synchronous. This type of orbit limits nadir viewing opportunities to approximately 52N and 52S latitudes, and results in variable ground illumination.

Daylight Orbits on ISS:
A – Successive ISS orbit paths, descending passes.
B – Daylight illumination in Southern Hemisphere only.
C – Successive ISS orbit paths, ascending passes.
D – Daylight illumination in Northern Hemisphere only.
Internal Payloads
Window Observational Research Facility
http://www.nasa.gov/mission_pages/station/research/experiments/WORF.html

- rack facility positioned over the US Destiny Lab module window (nadir-viewing)

- Station power and data connections, and multiple rack mounting options to support still and video cameras, multi/hyperspectral imagers, other instruments

- WORF shroud provides lighting control, secure payload space

- can support multiple instruments at the same time, and rapid instrument exchange

- window has high transmissivity (>90%) from 0.34 – 0.80 μm; drops off to 50% transmissivity between .80 and 1.3 μm

Expedition 27 astronaut Ron Garan working with ISSAC system and WORF. 6-May-2011.
**Sensor:** ISS Agricultural Camera, internal (WORF)

**Type:** paired digital line-scan cameras with filters

**Pointing capability:** 30 degrees cross track

**Geometric resolution:** 20-30 meters

**Spectral resolution:**
- visible green (0.52 – 0.60 μm)
- visible red (0.63 – 0.69 μm)
- near infrared (0.77 – 0.90 μm)

**Scene Size:** 21 km x 16 km at nominal altitude

**Data georeferencing:** automated, to order of 500 meters accuracy. Manual georeferencing possible to achieve 20 – 60 meter accuracy.

**Output file format:** standard Geotiff

**Data take to availability time:** ~ 24 – 48 hours

**Data availability:** Public

Sensor: COTS digital cameras, internal

Type: CCD

Pointing capability: yes, 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 resolution: visible RGB, poorly constrained bandpass (potential for NIR imagery using modified camera)

Scene Size: variable, depends on lens, ISS altitude

Data georeferencing: manual

Output file format: raw camera formats, JPEG, camera file with Meta data.

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

Data availability: Public
http://eol.jsc.nasa.gov

Left: Sahara Desert as seen through the ISS Cupola, 17-Feb-2010
NASA Payloads - CEO

Fire plume in the Chiracahua Mountains, AZ; [ISS027-E-31908](#), May 15, 2011, Nikon D3S, 200 mm lens

Higashimatsushima, Japan; [ISS026-E-33647](#), March 13, 2011, Nikon D2Xs, 800 mm lens

Sarychev Peak eruption column, pileus cloud, and pyroclastic flows; [ISS020-E-9048](#), June 12, 2009, Nikon D2Xs, 400 mm lens

Mississippi River flooding, MO and TN; [ISS027-E-27023](#), May 12, 2011, Nikon D2Xs, 400 mm lens
Planned NASA Payloads - ISERV

**Sensor**: ISS SERVIR Environmental Research and Visualization System, internal (WORF). Manifested on SpaceX flight, 2012.

**Type**: Schmidt-Cassegrain telescope with Canon Digital SLR camera on mount

**Pointing capability**: 23 degrees along and cross-track

**Geometric resolution**: < 3 meters nominal

**Spectral resolution**: visible RGB, poorly constrained bandpass; may be upgraded to include NIR with more sophisticated imager (0.35 – 0.80 microns)

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

**Data georeferencing**: unknown, may be possible to semi-automate with photogrammetric techniques

**Output file format**: raw camera format, JPEG (?)

**Data take to availability time**: ~ 3 hours nominal

**Data availability**: Public, through SERVIR nodes or other portals.
ISERV/SERVIR Applications

- Disaster Analysis
- Environmental Monitoring
- Air Quality and Public Health
- Climate Change and Biodiversity
- Short Term Weather Prediction

Landslide Mapping in Guatemala, January 2009
Fires in Guatemala and Mexico, April 2009
Earthquake Damage Assessment, Haiti January 2010
External Payloads
ISS External Research Facilities

Columbus External Payload Facility
(2 sites NASA, 4 sites total)

Kibo External Facility
5 sites NASA, 10 sites total

(ULF6, 2011)
**Sensor:** Hyperspectral Imager for the Coastal Ocean, external (JEM-EF)

**Type:** imaging spectrometer

**Pointing capability:** 45 degrees left of track, 30 degrees right of track

**Geometric resolution:** 90 meters nominal

**Spectral resolution:** 0.40 – 0.90 µm
87 useable bands, 5.7 nm resolution

**Scene Size:** 42 km x 192 km at nominal altitude

**Data georeferencing:** automated, rough geolocation in real time; improved geolocation data available 1-7 days later.

**Output file format:** BIL, BSQ with metadata

**Data take to availability time:** 48 hours.
Only 1 HICO scene/orbit, maximum 15 scenes/day

**Data availability:** By registered user request. Only data requested by user is available through HICO archive.
http://hico.coas.oregonstate.edu/datasearch/data-search-basic.php

HICO data for Galveston Bay area, TX; Left: RGB image. Right: water band (R), carotenoid reflectance (G), anthocyanin reflectance (B). 5-May-2011
Planned Cloud Aerosol Transport System (CATS)

- Cloud Physics LIDAR Instrument. Demonstrate multi-wavelength aerosol and cloud retrievals; planned for 2013 launch
- Provide cloud and aerosol data to help bridge the gap between CALIPSO and future missions (ACE).
- Enable aerosol transport models by using 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 PBL.
  - Passive aerosol measurements from space provide valuable constraints on column aerosol loading. However, models lack observational constraints on vertical distribution.
- ISS orbit is useful for tracking plumes and study of diurnal effects (not possible with A-Train orbit).

Snapshot of GEOS-4 model global aerosol distribution forecast for March 20, 2006. Orange = dust; Blue = sea salt; Green = smoke and sulfate; Saturation ~ species column amount

ISS orbit. The orbit inclination permits extensive measurements over aerosol source and aerosol transport regions.
Planned CATS-ISS Payload Hardware

Standard JEM-EF payload volume: 1.855 x 0.800 x 1.299 m.
HD video may represent another dataset of interest and use for atmospheric or other climate-related research (volcanic eruptions, flooding from high precipitation, wildfires, hurricane/tsunami, power outages/brownouts)

JSC Imagery Working Group involved with several initiatives:
- Continuous HD downlink of Earth views (HDEV) (720p)
- Support for JAXA SSHD
- Canon HDV camcorder onboard ISS

Issues to consider – data throughput on ISS LAN, downlink pipeline; ground storage of video, long term support for capability
The objective of the investigation is to evaluate different HD camera technologies in the LEO environment and in the process, provide high definition views of the Earth to interested parties and the public at large.

- Launching on SpaceX 3 in 2012

**COTS Parts**

**Cameras:**
- Toshiba IK-HR1s
- Hitachi GV-HD30
- Panasonic AGHMC150
- Sony FCB-EH4300

**Router**
- Extron SW4 3G HD-SDI

**Encoder**
- Visionary Solutions AVN443
BACKUP SLIDES
CEO Daily Target Message Ops

1. Potential targets determined using predicted ISS orbit ground tracks and defined areas of interest (+ 24 hours)
   - Dynamic event targets added manually
   - CEO ops performed Monday - Friday

2. Target list screened for viewing conditions, crew and ISS constraints (cloud cover, sun angle, viewing angle, crew wake/sleep, ISS manuevers) - these conditions have so far precluded acquisition of northern Japan test site

3. Final target list composed, with supporting data

4. Target list reviewed and uplinked through MSFC pipeline, available for crew review prior to scheduled wake time

   * Operational considerations for rapid response and image acquisition
CEO Process Following Target Uplink to Crew

1. CEO is a task-listed activity, therefore taking imagery with the handheld cameras at the designated times is at the crew’s discretion.

2. Imagery must then be copied from the camera back storage card into a specific downlink folder on a Station computer hard drive - timely placement of files for downlink is the responsibility of the crew.

3. Downlinked imagery classified as Earth Obs is then ingested by the CEO team and parsed into Priority 1 - imagery taken in response to a specific target request, as identified by the camera image file time; or Priority 2 (all other imagery). Note that neither the JSC Building 8 or CEO teams have the resources to provide 24/7 ground support. Priority 1 imagery is reviewed and cataloged by the CEO team, and added to the online database for public access.

4. Once imagery has been cataloged, automated email notification to interested parties is possible. At the present time CEO does not have a capability for automated notification based on Priority 2 imagery.

5. Other notification mechanisms involve direct communication from the crew themselves. CEO has occasionally received advance notice of imagery from the crew through comments made during DPCs, direct email communication, or even seeing imagery of events on astronaut’s Twitter feeds. But again, all of this is informal.

* Operational considerations for rapid response and image acquisition
Lidar (CPL) Data Example

Lidar profiling generates a time-height cross-section of the atmosphere, revealing cloud and aerosol structure.

Multiple cloud/layer features can be measured, up to the limit of signal attenuation (O.D. 3-4).

From this data we derive layer boundaries, optical depth, extinction, and depolarization, and at least a coarse discrimination of aerosol type (e.g., smoke, dust, pollution).

The CPL web site is:  http://cpl.gsfc.nasa.gov