The International Space Station: A Unique Platform For Terrestrial Remote Sensing

William L. Stefanov, Jacobs Technology/NASA Johnson Space Center, Houston, Texas USA, william.l.stefanov@nasa.gov; Cynthia A. Evans, NASA Johnson Space Center, Houston, Texas USA, cindy.evans-1@nasa.gov

Introduction. The International Space Station (ISS) became operational in November of 2000, and until recently remote sensing activities and operations have focused on handheld astronaut photography of the Earth. This effort builds from earlier NASA and Russian space programs (e.g. Evans et al. 2000; Glazovskiy and Dessinov 2000). To date, astronauts have taken more than 600,000 images of the Earth's land surface, oceans, and atmospheric phenomena from orbit using film and digital cameras as part two payloads: NASA's Crew Earth Observations experiment (http://eol.jsc.nasa.gov/) and Russia's Uragan experiment (Stefanov et al. 2012). Many of these images have unique attributes—varying look angles, ground resolutions, and illumination—that are not available from other remote sensing platforms. Despite this large volume of imagery and clear capability for Earth remote sensing, the ISS historically has not been perceived as an Earth observations platform by many remote sensing scientists. With the recent installation of new facilities and sophisticated sensor systems, and additional systems manifested and in development, that perception is changing to take advantage of the unique capabilities and viewing opportunities offered by the ISS.

ISS Orbital Attributes. The ISS orbits the Earth in an inclined equatorial orbit that is not sun-synchronous. The ISS passes over locations on the Earth between 51.6 ° north and 51.6 ° south latitude at different times of day, and under varying illumination conditions. During a typical yearly orbit cycle, illumination and viewing conditions over a given ground target will remain relatively stable for several days followed by a 60-70 day return interval to similar conditions (Gebelein and Eppler 2006). In contrast, unmanned satellite-based Earth observing sensors are typically placed onto polar-orbiting, sun-synchronous platforms like Landsat7—orbits designed to pass over the same spot on the Earth's surface at approximately the same time of day. These satellite platforms will revisit a location about every two weeks (Green and Lopez 2009). Collecting imagery with similar lighting conditions is desirable for producing uniform, easily comparable data for a specific place, but it also restricts the time that data is collected (near local solar noon in most cases). If an investigator is interested in a surface process that typically happens at other times of day, the data will be difficult to collect from the sun synchronous polar-orbiting satellites.

Human Involvement. Another unique advantage that the ISS offers in contrast to automated free-flyer sensor systems is the presence of a crew that can react to unfolding events in real time, rather than needing to receive a new data collection program uploaded from ground control. This is particularly important for collecting imagery of unexpected natural hazard events such as volcanic eruptions, wildfires, and tropical storms, as well as ephemeral atmospheric phenomena such as aurora and noctilucent clouds. The crew also can decide whether or not viewing conditions – like cloud cover or illumination – will allow useful data to be collected, as opposed to a robotic sensor that collects data regardless of quality (Evans et al. 2011).

ISS Sensor Systems and Facilities. Automated sensor systems and facilities on board the ISS – both internal and external – provide for exciting new capabilities for Earth remote sensing. Individual science teams currently manage the access to data collected by the various sensor systems, but a central data access facility is planned for the future. Several systems managed by NASA and international partner agencies for Earth observation are now onboard and operational or manifested for transport. Internal facilities include the Window Observational Research Facility (http://www.nasa.gov/mission_pages/station/research/experiments/WORF.html), or WORF, that provides a highly stable internal mounting platform over the US Destiny Laboratory window to hold cameras and sensors steady, in addition to power, command, data, and cooling connections.

Sensor systems currently operated in the WORF include the International Space Station Agricultural Camera (http://www.nasa.gov/mission_pages/station/research/experiments/ISSAC.html), or ISSAC, developed by the University of North Dakota. ISSAC collects multispectral data supporting agricultural activities and related research in the Upper Midwest of the United States. In addition the ISSAC can be tasked to collect imagery of natural hazards in support of NASA humanitarian efforts. ISSAC data is collected in the visible and near-infrared wavelengths (3 bands) at a nominal ground resolution of 20 meters/pixel (Olsen et al. 2011).

The International Space Station SERVIR Environmental Research and Visualization System, or I-SERV, is a sensor system manifested for flight in 2012 for installation in the WORF. The system consists of a Schmidt-Cassegrain telescope mated to a digital camera system to collect visible-wavelength imagery at ground resolutions of less than 3 meters/pixel. The sensor is intended to support the NASA SERVIR program (http://www.nasa.gov/mission_pages/servir/index.html)in its goals of using Earth science data to aid the developing world, mitigate and respond to disasters, and provide humanitarian support. It will also serve as a testbed for future free-flyer instruments.

Currently, the only externally mounted ISS system that is active is the Hyperspectral Imager for the Coastal Oceans (http://hico.coas.oregonstate.edu/index.shtml), or HICO, mounted on the external facility of the Japanese Kibo module (Lucke et al. 2011). The prime mission of HICO is to collect data on water clarity, bottom materials, bathymetry, and onshore vegetation along the coasts of Earth's oceans at approximately 90 m/pixel ground resolution. The sensor collects high-quality information in 87 bands over the visible and near-infrared wavelengths. An earlier JAXA payload, the Superconductor Submillimeter-wave Limb-Emission Sounder, or SMILES (http://smiles.tksc.jaxa.jp/), mapped global distributions of stratospheric trace gases that relate to stratospheric ozone levels.

ISS Earth Observations also supports educational initiatives. A long-standing program, EarthKAM (https://earthkam.ucsd.edu/), enables middle school students to collect imagery of the Earth's surface by commanding a camera set up in an ISS window. To date, this program has acquired tens of thousands of images by students from around the world, and involved approximately 100,000 students.

The combined capabilities of both human-operated and autonomous sensor systems onboard the ISS promise to significantly improve our ability to characterize and monitor Earth system processes, and will enhance our capabilities for natural hazard observation and response. Integration of the ISS remote sensing capabilities represents a significant and complimentary addition to the international satellite based Earth Observing "system of systems" providing knowledge and insight into our shared global environment.

References

Evans CA, Lulla KP, Dessinov LV, Glazovskiy NF, Kasimov NS, and Knizhnikov YF, 2000. Shuttle-Mir Earth science investigations: Studying dynamic Earth environments from the Mir Space Station. In: Lulla KP, and Dessinov LV (eds.), Dynamic Earth Environments: Remote Sensing Observations from Shuttle-Mir Missions. John Wiley & Sons, New York, NY, pp. 1-14

Evans CA, Wilkinson MJ, Stefanov WL, and Willis K, 2011. Training astronauts to observe Earth from the Space Shuttle and International Space Station. In: Garry WB, and Bleacher JE (eds.), Analogs for Planetary Exploration. Geological Society of America Special Paper 483, pp. 67-73

Gebelein J, and Eppler D, 2006. How Earth remote sensing from the International Space Station complements current satellite-based sensors. International Journal of Remote Sensing 27 (13):2613-2629

Glazovskiy NF, and Dessinov LV, 2000. Russian visual observations of Earth: Historical perspective. In: Lulla KP, and Dessinov LV (eds.), Dynamic Earth Environments: Remote Sensing Observations from Shuttle-Mir Missions. John Wiley & Sons, New York, NY, pp. 15-23

Green K, and Lopez C, 2009. Basics of remote sensing systems. In: Jackson MW (ed.), Earth Observing Platforms & Sensors, Manual of Remote Sensing Vol. 1.1 (3rd Ed.). American Society for Photogrammetry and Remote Sensing, Bethesda, MD, pp. 49-106

Lucke RL, Corson M, McGlothlin NR, Butcher SD, Wood DL, Korwan DR, Li RR, Snyder WA, Davis CO, and Chen DT, 2011. Hyperspectral Imager for the Coastal Ocean: instrument description and first images. Applied Optics 50 (11):1501-1516

Olsen DR, Kim HJ, Ranganathan J, and Laguette S, 2011. Development of a low-cost student-built multi-spectral sensor for the International Space Station. Proceedings of the SPIE 2011 Optics + Photonics Conference, 21-25 August, San Diego, CA, abstract 8153-23

Stefanov WL, Evans CA, Runco SK, Wilkinson MJ, and Willis K, 2012. Astronaut photography: Handheld camera imagery from Low Earth Orbit. In: Pelton JN, Madry S, and Camacho-Lara S (eds.), Handbook of Satellite Applications. Springer, Berlin (in press)