# Crew's Remote Sensing Researches on the International Space Station

Joo-Hee Lee, Gi-Hyuk Choi, Yeon-Kyu Kim, and Jong-Woo Kim
Satellite Operation & Application Center,
Korea Aerospace Research Institute
45 Eoeun-dong Yuseong-gu, Daejeon 305-333, Korea
jhl@kari.re.kr
gchoi@kari.re.kr

**Abstract:** The International Space Station (ISS) offers research opportunities to researchers through crew's space mission in the field of remote sensing. ISS provides the facilities to place and operate experiment equipments in a variety of fields, especially, microgravity experiments and Earth observations. This paper is intended to give readers a brief introduction to the ISS utilization and the capabilities for remote sensing researches. We investigate what kind of crew missions and payloads should be developed for remote sensing researches on the ISS.

**Keywords:** ISS, Crew Earth Observations, Space Mission.

## 1. Introduction

Earth observation from space is new to Korea, but is not new to the United States or Russia. Two countries have a lot of experience and historical archives for documenting changes on Earth's surface from low Earth orbit. The primary goal of Earth observations was to use astronaut and cosmonaut photographs to document environmental changes and dynamic Earth process such as flooding and droughts, urban growth and land use changes around the world, events related to El Nino, and transient phenomena such as tropical storms, large fires, and volcanic eruptions. A second important objective of early Earth observations experiment was to use an operational environment to develop approaches and tools for the next generation of Earth observations from the International Space Station (ISS).

ISS has an extraordinary optical quality window - the best ever flown on a manned spacecraft. The optical-quality window in the U.S. Destiny Laboratory became part of the orbiting outpost in February 2001, with the Window Observational Research Facility (WORF) support system. Since that time, ISS crew have become happy, picking their shots of Earth using digital still cameras, 35-mm and 70-mm cameras, and making use of a range of lenses. The first three resident space station crews clicked nearly 13, 500 pictures of our home planet. In the process, a new standard has been set for Earth photography. An analysis of the images found that objects less than 6 meters across on Earth can be resolved using cameras on board the high-flying ISS. Clearly, researchers can use the ISS as a platform from which to study the workings of our world, regularly monitoring very small features and change around the world.

NASA astronauts and Russian cosmonauts have used hand-held cameras to photograph the Earth for more than 30 years. Since 1981, Space Shuttle astronauts have taken photographs of the Earth. Also, ISS continues the Earth observation with crews. Figure 1 shows the location of astronaut photographs taken by NASA Shuttle/ISS crews.

Astronauts including ISS crews are trained in scientific observation of ecological, geological, geographic, oceanographic, environmental and meteorological phenomena. They are also instructed in the use of photographic equipment and techniques. Preflight training helps the astronauts make informed decisions on which areas and phenomena to photograph. Specific areas of scientific interest are selected before each flight by a group of researchers.

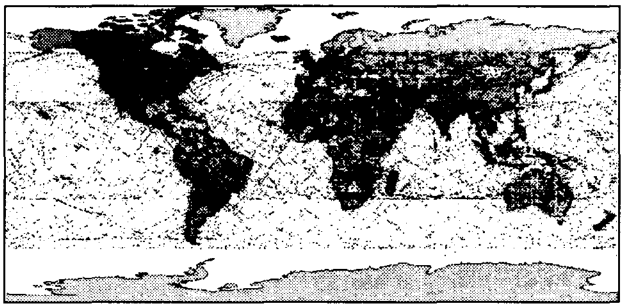

**Fig 1. Location of Astronaut Photographs (NASA, April 2000)**

## 2. Photographic Characteristics of Earth Observation and Research Window

Most of photographs are in natural color. Color infrared film has also been used on some missions, and a small amount of black-and-white film has been used with polarizing filters. A number of lenses and film formats have been used producing a wide variety of both aerial coverage and spatial resolution.

The Shuttle flies at altitudes ranging from 213 to 617 km, resulting in variation in coverage and resolution. The shuttle orbital track typically covers the tropical and temperate regions of the Earth between 28 degrees N and 28 degrees S latitude, but other missions have flown up to 57 degrees N and 57 degrees S latitude. Repeat coverage of an area is obtained by acquiring photographs on several missions and by taking photographs from different viewing angles during a single mission. An area may be photographed at different Sun angles during a single

mission as a result of the Earth's rotation and the duration of the orbits (approximately 90 minutes). Stereoscopic coverage is available for a number of areas. [4]
ISS has an average altitude of 407 km with an orbital inclination of 51.6°. Due to the westward precession of orbit tracks, the ISS flies over the same area on the Earth's surface about every 3 days and it covers the same lighting conditions about every 3 months as shown in figure 2.

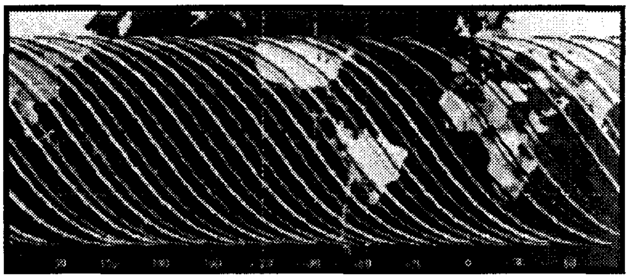

**Fig 2. ISS Orbits; Daylight, 3-day Repeat (K. Lulla/NASA-JSC)**

The U.S. Laboratory Module on the ISS has a window (WORF, Fig. 3), with a clear aperture 50.8 cm in diameter, which is perpendicular to the Earth's surface most of the time. The window's three panes of fused silica give it "optical quality." Instrumentation for Earth observation include Hasselblad, Linhof, and Nikon hand-held cameras, plus sensors and imaging systems still to be developed. The WORF can take advantage of a variety of payload opportunities, involving both astronaut-operated and autonomous operations, covering a number of different Earth observation missions, including observations of ephemeral events such as oceanfront, and dust plumes as well as episodic events, such as floods, volcanic eruptions. The WORF rack provides support instruments for camera and remote sensor operations.

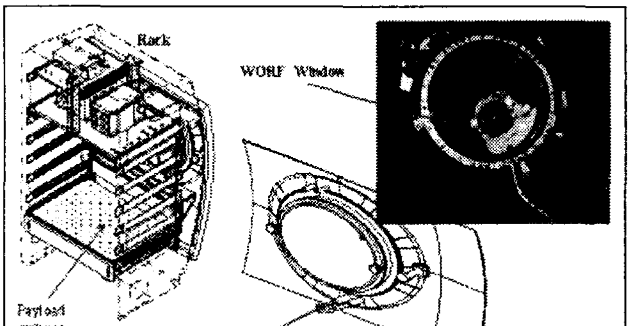


**Fig 3. Window Observational Research Facility (NASA)**

From collecting data for Remote Sensing and Earth science, such as geology, oceanography, meteorology, or Earth observation, to testing new sensor performance, the WORF provides good opportunities for scientists who need the flexibility of a crewed space platform. The optical quality of the window allows multi-spectral instruments to use the visible and near-infrared spectrum. The advantage of the ISS being in Low Earth Orbit (LEO) provides a unique vantage point for collecting remote sensing data of the Earth.

## 3. Earth Observations on the ISS

There are four payloads either being manifested or gotten a high degree of interest by various partner organizations for flight on the ISS.

• *SAGE III*: SAGE III is scheduled to be a part of the ISS payload beginning in 2004 but this project is delayed due to Columbia accident. ISS is placed in a 51°-inclined orbit that yields SAGE III solar measurement opportunities from 70° South to 70° North over the course of one month. This orbit is similar to that of SAGE II (a 57°-inclined orbit) and is well suited to SAGE III's primary mission to provide long-term global monitoring of ozone and aerosol variations.

• *FOCUS*: FOCUS is a proposed payload by ESA that will look for biomass burning. At present, ESA is debating their priorities between FOCUS and another, non-Earth observing payload.

• *EarthKAM*: EarthKAM is an educational payload sponsored partly by Code Y for the development of geographic knowledge among middle school students. It is scheduled to fly early stage of the assembly sequence and will use both the U.S. Lab window and the Russian Service Module window

• *A complement set of cameras*, including Nikon F5 35mm, and Nikon electronic still camera, with a variety of lenses up to 400 mm telephoto, are currently manifested for ISS utilization.

A number of payload developers have expressed interest in putting Earth Observations & Applications Payloads on the ISS.

• *Hyperspectral Scanner*: George May (Stennis Space Center)

• *Laser Altimeter*: Jack Bufton and Jim Garvin (Goddard Space Flight Center)

• *Coral Reef Imaging*: Paul Lucey (University of Hawaii)

Earth observation data have a variety of application fields such as following;
Land-use change is a major focus of the target sites originally planned for ISS Earth observations. These includes many environmental situations that are well studied by the Russian scientists, such as the desiccation of the Aral' Sea, the Caspian Sea, and the regional impacts of these events. On other countries, target sites emphasized regions undergoing dramatic changes in land use, such as forest conversion in the Amazon basin, biomass burning and other changes in parts of Africa and South Asia, and expansion of urban regions worldwide.
Seasonal change and long-term climatic effects can readily be documented by looking at water bodies. Regional water issues around the world is deemed of high priority because they are factors in climate change investigations and directly affect regional land use, local ecology, and the quality of human life.

ISS plans to take advantage of the longer-duration missions to document dynamic events over periods equal to or shorter than seasons. A relatively new focus is on aerosol production (dust, smog, smoke) around the world. These data are becoming increasingly important in climate change modeling, material transport, and land-use change. Regions that ISS targeted as places to watch for atmospheric events such as dust storms and the production of aerosol blankets include the Sahara and central Andes (dust); the Red Basin of China and the South Africa industrial core (smog); and the Amazon basin during the burning season (smoke).
ISS also choose sites with short-term natural dynamics. Ocean processes such as plankton blooms, ocean frontal systems, internal waves, and current boundaries are to be documented wherever observed in the equatorial Pacific, the Arabian Sea, the Gulf Stream, and at convergences of currents off the Argentinean coasts.
Several of the most active and rapidly changing volcanic regions are chosen for observations as well. [2]
Summary of significant Earth photographs from ISS crew missions are following;

- *Land use change*
- *Seasonal change and long-term climate change*: snow pack, glacier, snowlines, snow levels, snow blanket, icepack, drought, water levels, flooding, cloud cover, lake and sea ice, vegetation etc.
- *Atmospheric events*: dust, dust storms, smoke, smog, thunderstorms, tropical storms, cloud patterns, haze etc.
- *Oceans and coastal dynamic features*
- *Volcanoes*
- *Cities and regional targets*

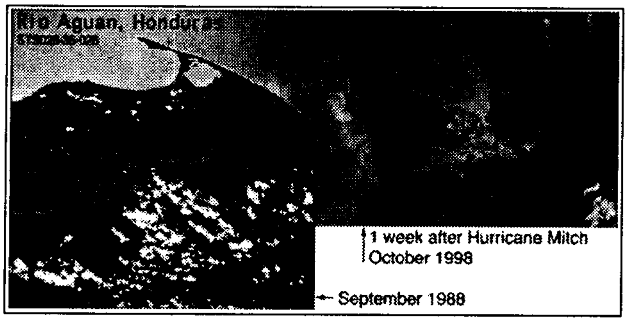

**Fig 4. Example: Flooding in Honduras resulted in Cholera (NASA)**


**Fig 5. Example: Flooding in Madagascar (NASA)**

## 4. Conclusions

ISS has the potential to be a valuable platform with window from which to observe the Earth. Scientists can use the ISS for conducting multi-spectral observations of Earth's land, oceans, and atmosphere. We can also take advantage of the longevity of ISS to observe global changes, geologic activity, land use and agricultural production through remote sensing observations.
Ministry of Science & Technology (MOST) and Korea Aerospace Research Institute (KARI) are preparing for the first Korean Astronaut Program based on the mid and long-term basic plan for space development of Korea from the year of 2003. KARI is making plans for an astronaut selection and training with Russia including Korean astronaut's mission. To participate in the ISS utilization through Korean astronaut, KARI investigates manned space experiment missions. The following subjects are the major expected experiment areas for a Korean astronaut.

- *Earth science (Earth Observation)*
- *Biology*
- *Physiology*
- *Physical Science*
- *Technology*
- *Education*

KARI hopes that Korean scientists suggest many kinds of astronaut's missions in the above fields to utilize the ISS for their researches.

## References

[1] J. H. Lee, G. H. Choi and H. Y. Paik, 2002. Remote Sensing Opportunities on the International Space Station, *Proceedings of ISRS 2002*, Sokcho, Korea.
[2] Kamlesh P. Lulla and Lev V. Dessinov, 2000, Dynamic Earth Environment, John Wiley & Sons, Inc., New York, pp. 5-13.
[3] Robinson, J. A. and C. A. Evans. 2002. Space Station Allows Remote Sensing of Earth to within Six Meters. Eos, Transactions, American Geophysical Union 83 (17):185, 188.
[4] **URL**: NASA's Earth science and Public Health Program; Space Shuttle/International Space Station Earth Observation Photography: Imaging for Human Health Applications, Available at http://healthyplanet.gsfc.nasa.gov/shuttle .pdf.
[5] **URL**: The Gateway to Astronaut Photography of Earth, Available at http://eol.jsc.nasa.gov.
[6] **URL**: The Gateway to Astronaut Photography of Earth, Available at http://earth.jsc.nasa.gov.