Remote Sensing Research Opportunities on the International Space Station

- Preparing to Participate in the ISS Program -

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Abstract

The International Space Station (ISS) offers research opportunities for researchers in the field of remote sensing to conduct world-class activities in Low Earth Orbit. ISS provides the facilities to place and operate research experiments in a variety of fields, providing investigators opportunities to perform research and Earth observation. This paper is intended to give the reader an introduction to the ISS utilization and the capabilities for remote sensing research that are being implemented through the development of research facilities. We hope that reader will consider what kind of payloads could be developed to take advantage of facilities, and will consider proposing remote sensing research on the ISS.

1. Introduction and ISS Characteristics

The time has come to give an important thought to the use of the International Space Station (ISS) as a platform to advance remote sensing research fields. ISS offers good opportunities for researchers to conduct world-class activities in Low Earth Orbit. The configuration of ISS after completion of assembly is shown in Figure 1.

The ISS flies over the temperate and tropical regions of the Earth as shown in Figure 2, covering approximately 85% of the Earth's land area and approximately 95% of the Earth's population. The ISS has an average altitude of 407km (350km ~ 470km) with an orbital inclination of 51.6°. The ISS will be boosted to its maximum altitude every 90 days and allowed to drift down to its minimum altitude.

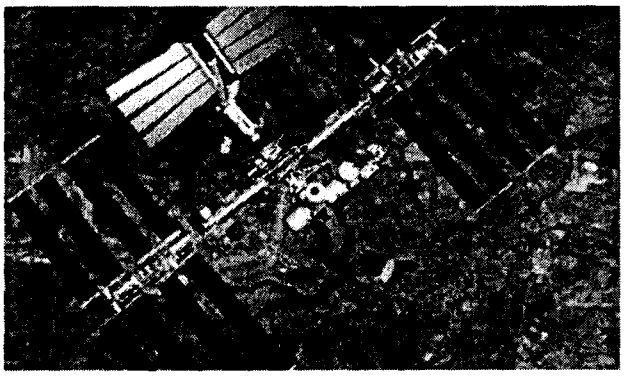


Fig. 1 International Space Station
(Animation Still Image by NASA)

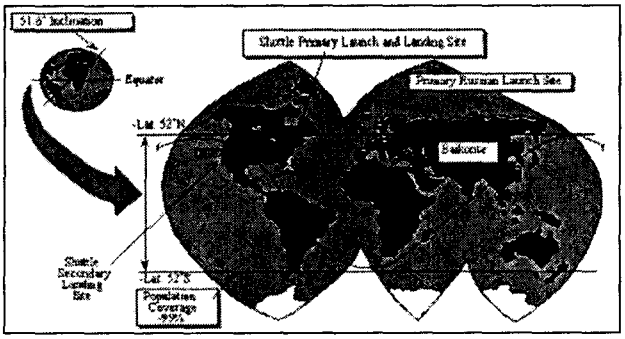


Fig. 2 ISS Orbital Coverage [1]

Due to the westward precession of orbit tracks, the ISS will fly over the same spot (area) on the Earth's surface about every 3 days and it will cover the same lighting conditions about every 3 months (Fig. 3).

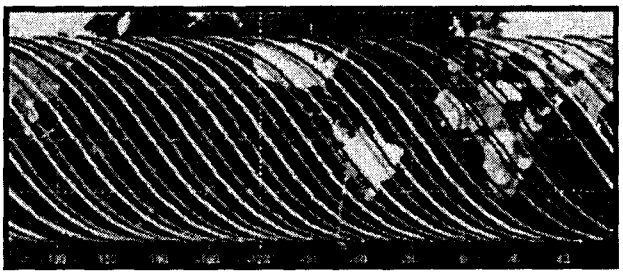


Fig. 3 ISS Orbits; Daylight, 3-day Repeat
(K. Lulla/NASA-JSC)

The utilization of the ISS by users has already begun

with experiments in the Zvezda service module, and the U.S. laboratory module Destiny, and it will continue with facilities and resources throughout the rest of the assembly phase. The benefits that the ISS offers to users include;

• The capability to perform an experiment and observation program over an extended period of time in weightless conditions,
• The capability to perform iterative research on a short time scale through the provision of regular access to and return from the ISS,
• Provision of access to a significant level of resources,
• The permanent presence of crew,
• An extensive range of facilities to enable activities in a large number of utilization fields (William et al., 2001)

A summary of the ISS key characteristics is provided in Table 1.

Table 1. ISS Specifications

Parameter	Characteristic
Truss Length	108 m
Module Length	74 m
Mass	~420 ton
Max. Power Output	110 kW
Total Pressurized Volume	1,200 m^3
Atmospheric Pressure	1 atmosphere
Altitude	350~470 km
Inclination	51.6 degrees
Velocity	~8 km/sec
Attitude	Local Vertical & Horizontal
Max. Crew	7
Lifetime	>10 years

2. Research Opportunities on the ISS

The ISS will provide opportunities for external attached payloads at several locations for earth and space science payloads. It means that there is a platform on the ISS for many different types of Earth viewing sensors. These locations are sited at the United States Starboard Truss and consist of the Expedite the Processing of Experiments to Space Station (EXPRESS) Pallet, the Japanese Experiment Module-Exposed Facility (JEM-EF), and Columbus External Payload Facility (EPF). Each external site offers unique capabilities and environments. In addition to these external sites, there are additional research opportunities that are an internal facility, the pressurized Window Observational Research Facility (WORF) in the U.S. Laboratory Module. Many years of planning have culminated in the launch of the elements of the ISS, including the Destiny laboratory Window Observational Research Facility (WORF). [2]

Figure 4 shows the external attached payload sites on the ISS. Earth viewing sensors for remote sensing can be mounted both external payloads sites and internal in the station. Therefore Earth observation experiments can be conducted to get data from sensors flown at external attached sites or from sensors in the WORF. A big difference between the ISS and most satellite's remote sensing, and an advantage is the continuous presence of man. Astronauts' presence on the ISS has following advantages in several ways.

• The capability of investigator's interaction with their payloads directly from the ground, it will improve the utility and quality of the research outputs.
• Payloads can be deployed, recovered for periodic calibration, repair or maintenance, and then redeployed.
• Malfunction of payloads can be recovered and returned to Earth for repairs.
• These activities can improve the values of the data set.

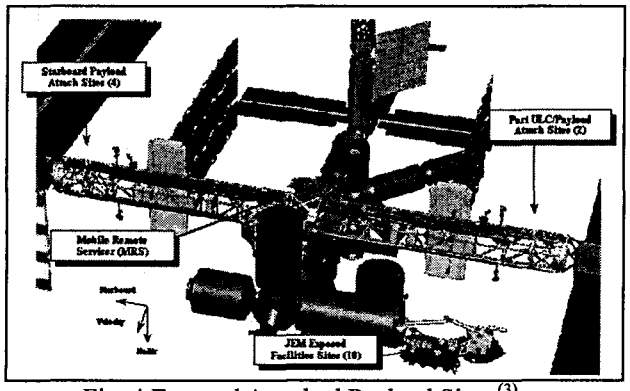


Fig. 4 External Attached Payload Sites [3]

ISS has high repeat coverage in the mid-latitude range of 52° north to 52° south. The high repeat coverage in some of these areas is extremely important because these areas can be covered by cloud or fog much of time. Overflight of the same area every three days provides a repeat coverage that can be used to monitor quickly changing phenomena such as the growth of crops, sediment discharge changes, damage due to fires, earthquakes, hurricanes or heavy rains and flooding. These types of observations may be helpful for human health and safety issues as well as keeping track of landscape change after a natural disaster. Greater temporal resolution of land use and land cover change in the areas of special interest such as rural urban fringes can aid researchers to spot the areas of significant changes and to find the causes of such changes (Dean et al., 1999).

ISS accommodates four starboard side U.S. attached

payload sites on the S3 truss. The ISS attach sites have a standard payload envelope and mass capability. Each attach point can support an individual payload up to 5000 kg, or up to six smaller payloads up to 225 kg each on an Express Pallet. Actual maximum mass of payload is a complicated function of mass, size, and center of gravity. In addition to the four attach sites, ISS designates the P3 sites for use of Unpressurized Logistics Carrier (ULC). Use of the P3 sites for payloads is not available currently because of the logistics requirements. Reassessment of the long-term logistics requirements for the P3 sites will be studied over the next year. If it appears to have a room at the P3 sites for payloads after completion of assembly, the use of these sites for the payloads will be evaluated.

2.1 EXPRESS Pallet

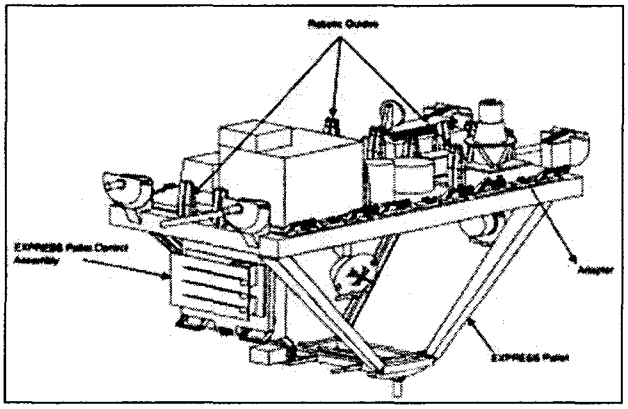


Fig. 5 EXPRESS Pallet [4]

There are four external attach sites on the starboard side of the ISS. There are two attach points on the nadir (Earth-facing) side and two on the zenith side of truss (Fig. 5). The EXPRESS Pallet is the ISS's Carrier/ Facility for small payloads, allowing a single attached point to accommodate up to 6 small payloads. Utilization baseline of the ISS external accommodations is specified in the Truss Payload Attach System and the guideline is restricted by the operational envelope, robotics capability and logistics carriers. Total of 4 pallets is being built with 6 payload adapters per pallet. Current traffic model calls for three EXPRESS pallets and the AMS on the 4 S-3 sites.

- Payload volume per pallet adapter: 1.1 (l) x 0.86(w) x 1.2 (h) m
- Payload weight: up to 227 kg
- Power: up to 2.5 kW @ 113 VDC, up to 500 W @ 28 VDC, both share resources
- Command, Control and Data: MIL-STD-1553 for command & control, Ethernet up to 10 Mbps, both share resources
- Thermal Control: none provided to payloads
- Fields of View: Nadir, Zenith, Ram, Wake, and Earth Limb

Recently, NASA opened competitions for scientific programs to be supported as "Missions of Opportunity" to utilize the EXPRESS Pallet on the ISS. A single EXPRESS Pallet has the capability of carrying instruments similar to the payload of a satellite. As the ISS becomes fully operational, EXPRESS Pallets could be deployed in short periods of time compared to preparing a satellite program.

2.2 WORF

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. ISS WORF (Fig. 6) has 20-inches diameter window located in the nadir side of the U.S. laboratory module. Optical quality of window is superior to any window flown on a manned mission. Measured optical quality confirms wavefront error of $\lambda/14$ over 6-inches, peak to valley, reference of λ=632.8 nm, with scratched pane removed for payload operations. WORF rack provides support instruments for camera and remote sensor operations.

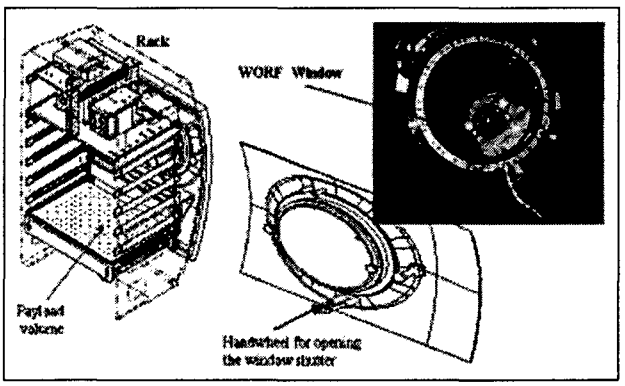


Fig. 6 Window on Orbit [3]

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 provides a unique vantage point for collecting Earth Science & R/S data.

3. Missions of Opportunity

NASA Office of Space Science (OSS) has allocations for two zenith-pointing EXPRESS Pallet Adapter payloads, available beginning in 2007. Information on the specifics of the EXPRESS Pallet, including interfaces, available payload resources, costing information, and a point of contact from the OSS Research Program Office for ISS Utilization, may be found in the International Space Station Research Opportunities document in the Explorer Program Library.

The current preliminary date for the launch of the first zenith EXPRESS Pallet and integrated payloads are no earlier than February 2007. Potential proposers must contact the point-of-contact in the International Space Station Research Opportunities document to learn of any significant change to this milestone. If the milestone is delayed beyond the period covered by this Announcements of Opportunity (AO), NASA intends to offer ISS opportunities in subsequent Explorer AO's.

A Mission of Opportunity investigation may also be proposed to fly on the ISS as a full truss site payload. An investigation may only be proposed for the ISS full truss site if it cannot be accommodated on other standard ISS sites. Since only one full truss site may be available for investigations proposed to this AO, then, at most, only one full Small Explorers (SMEX) investigation or one Mission of Opportunity investigation can be selected for the ISS full truss site through this AO. The accommodation capabilities of the ISS sites are described in the ISS Research Opportunities document in the Explorer Program Library. ISS full truss site payloads must have a launch readiness date of February 2007.

Opportunities for payloads intending to use the ISS Window Observational Research Facility (WORF) are also offered under this AO. The WORF accommodates Earth viewing observations through the window in the U.S. laboratory. Payloads using the WORF remain within the pressurized volume of the ISS. Specific accommodation information for WORF payloads can be found in the ISS Research Opportunities document in the Explorer Program Library. The WORF itself will be placed in the ISS in 2003. Multiple payload flight opportunities exist starting in 2003. [5]

3.1 Payload Selection

The NASA Office of Earth Science (OES) will select ISS payloads through their existing Announcement of Opportunity (AO) processes. Opportunities exist for attached payloads and pressurized payloads in the WORF. Due to the global coverage of the ISS orbit, ISS payloads are appropriate for most of Earth science & R/S disciplines. The OES uses both AOs and NASA Research Announcements (NRA) to fund research. Opportunities for both attached payloads and WORF payloads will be offered under the Earth System Science Pathfinder (ESSP) and University Earth System Science (UnESS) AOs. WORF payloads may also be selected by NRAs. The ISS Payloads Office and NASA Advisory Committees have worked since 1989 to develop and improve the Earth sciences research capability on the ISS. Opening the UnESS AO for ISS payloads is the first step in flying Earth sciences applications payloads on the ISS.

3.2 Proposed Earth Science Payloads in U.S.

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. ISS will be 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)

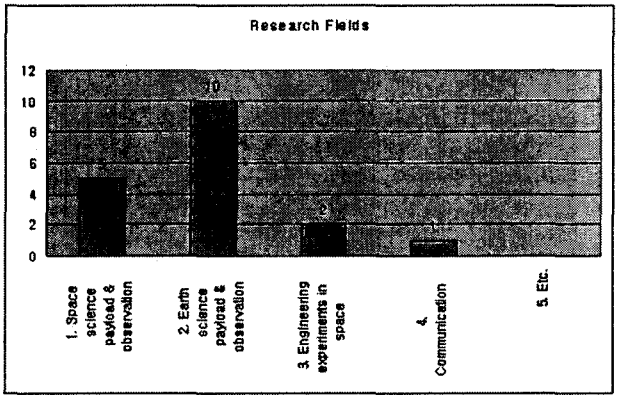
• *Laser Altimeter*: Jack Bufton and Jim Garvin (Goddard Space Flight Center)

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

4. KARI's Survey Analysis for the ISS Utilization

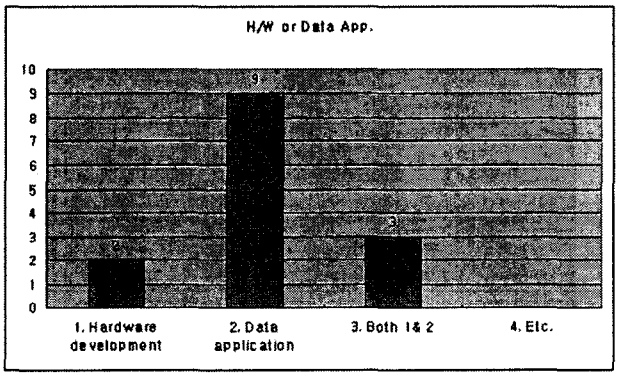
KARI is trying to participate in the ISS program and international cooperation research such as payload support & interface module development, space & Earth science experiment, microgravity experiment etc.

We carried out the survey for one month to look into user's utilization fields of the ISS in March 2002. Users have various ideas for ISS utilization plan according to their research fields. We have sent questionnaires to 32 researchers (26 organizations). And 14 researchers (13 organizations) have replied these questionnaires. Figure 7 to 10 show the major results of questionnaire analysis for ISS utilization.



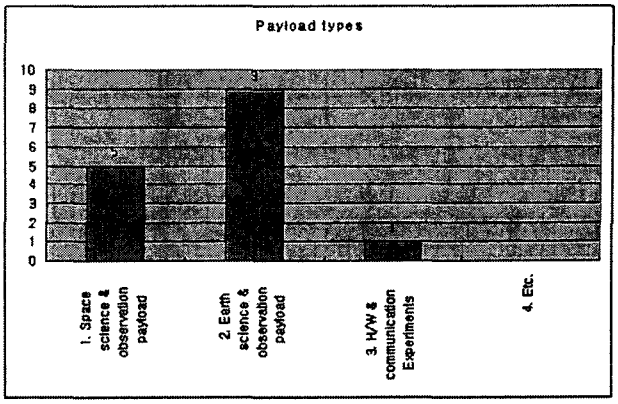
Q. Please tell us about your interesting research field in the ISS.

Fig. 7 User's Interesting Research Fields



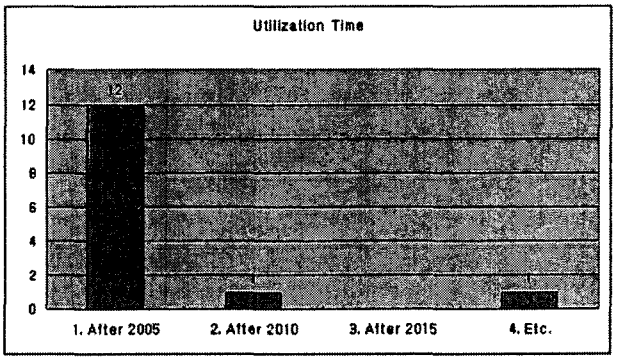
Q. Which research fields do you want to participate in H/W development or data application on the ISS payload attached sites?

Fig. 8 User's Participating Research Fields



Q. Payloads on the ISS attached sites are supposed to use the ISS's power, command, and data relay system. If you can develop payloads using these systems, what kind of payloads would you like to develop?

Fig. 9 User's Suggesting Payload Types



Q. Please tell us your time schedule, which you prefer to utilize the payload on the ISS payload attached sites.

Fig. 10 ISS Utilization Time

Korean scientists suggest many kinds of payload to utilize the ISS for their research in the future. The following lists are the major suggested payloads. It is included Earth Science & R/S, Space Science, and Life Science & Others.

Earth Science & R/S

- Radar Altimeter Sensor; K.H. Gi, KIGAM
- GPS Remote Sensing; J.W. Kim, Sejong University
- Earth Environment Observation Sensor; Y.J. Kim, KJIST

Space Science

- ACCESS Payload Development; I.H. Park, Eawha University
- ACCESS Payload Support & Interface Module Development; H.Y. Paik, KARI
- Far-ultraviolet Imaging Spectrograph; W.Y. Han, KAO
- Extreme Ultra-violet Telescope; S.J. Kim, Kyunghee

University
- Monitoring Space Environment Sensor; K.W. Min, KAIST

Life Science & Others
- Biotechnology Experiments; S.J. Kim, KRIBB
- Space Flight Environment; M.B. Gu, KJIST
- Astronaut Training; W.K. Lee, KAAM & G.H. Choi, KARI

5. Conclusion

ISS has the potential to be a valuable platform with WORF or external payload attached sites from which to observe the Earth and the universe. 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 including remote sensing over many years. To participate in the ISS utilization, KARI performed survey to investigate ISS utilization fields and payload types. As the results of survey, KARI will prepare for participation of the ISS utilization program.

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