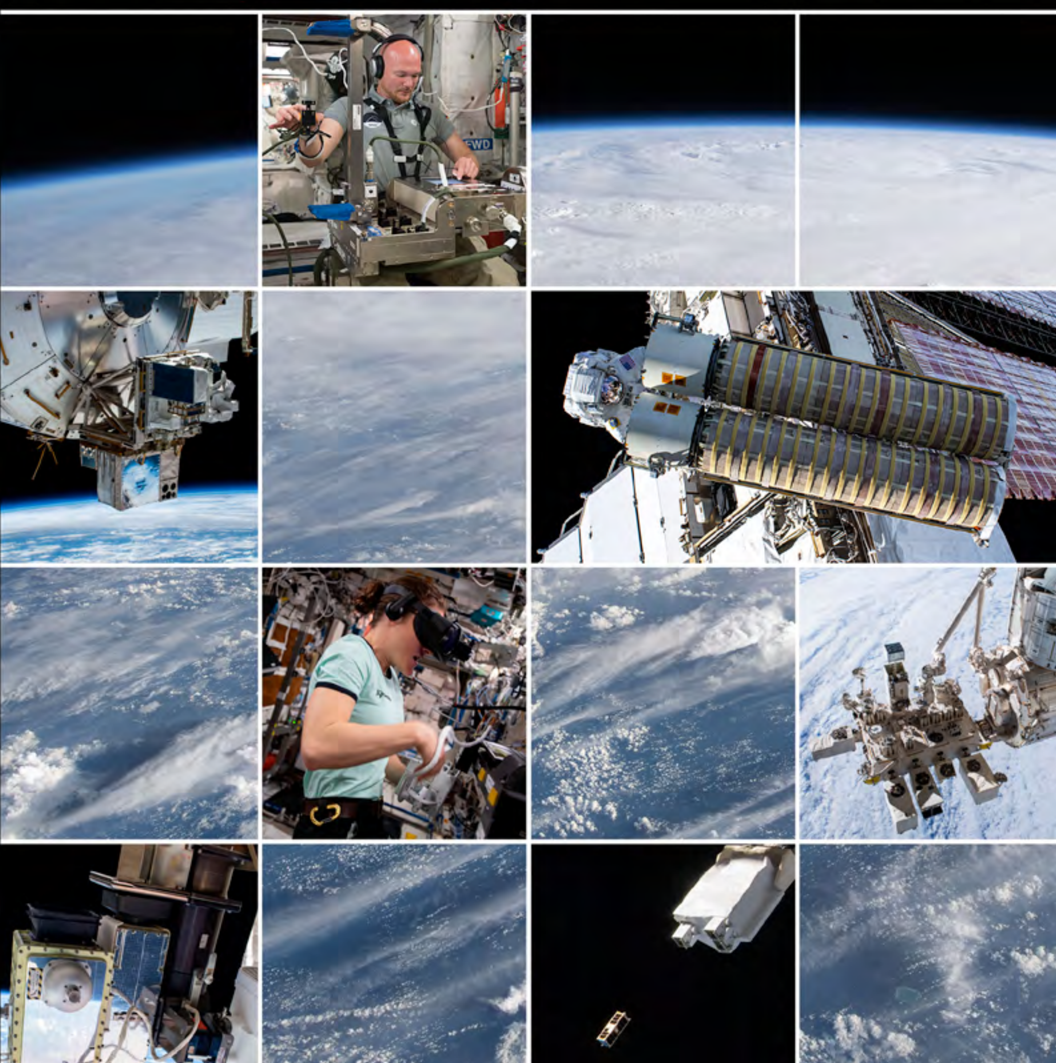
National Aeronautics and Space Administration

A Researcher's Guide to:

INTERNATIONAL SPACE STATION

Technology Demonstration



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Cover and back cover:

a. Over a background of Earth cloud masks, photos are from left to right, top to bottom:

- *ESA (European Space Agency) Astronaut Alexander Gerst participates in the Grip study in the Columbus Module. Grip is an ESA-sponsored experiment researching adaptation of the nervous system to microgravity.*
- *View of Space Test Program - Houston #7 (STP-H7) taken by External High Definition Camera 3 (EHDC3) during Expedition 66. The STP-H platform hosts multiple external payloads from various institutions.*
- *(Two panes) NASA spacewalker Shane Kimbrough carries the second roll out solar array toward the International Space Station's Port-6 truss structure for installation.*
- *NASA astronaut and Expedition 59 Flight Engineer Christina Koch wears a virtual reality headset during Virtual Reality Training (VRT) on orbit for refamiliarization training prior to an EVA.*
- *The Kibo laboratory module from the Japan Aerospace Exploration Agency, comprised of a pressurized module and exposed facility, a logistics module, a remote manipulator system and an inter-orbit communication system unit, is pictured as the ISS orbits over the southern Pacific Ocean east of New Zealand.*
- *View of an External High Definition Camera (EHDC) newly installed at Camera Port 9 (CP9) on the P1 Truss during Extravehicular Activity 37.*
- *Deployment of the AQT-D CubeSat from the JEM Small Satellite Orbital Deployer aboard the ISS. AQua Thruster-Demonstrator (AQT-D) is a 3U CubeSat demonstration of a water resistojet propulsion system developed by The University of Tokyo.*

Back cover:

b. NASA and Made in Space are collaborating to better understand the behavior of 3D printing in zero gravity and recently launched a polymer recycler to the ISS. Astronauts test the processing of raw plastic materials and convert plastic packaging and trash into usable 3D printing feedstock for 3D-printed parts and tools.

c. Several tiny satellites are featured in this image photographed by an Expedition 33 crew member on the ISS. The satellites were released outside the Kibo laboratory using a Small Satellite Orbital Deployer attached to the Japanese module's robotic arm. A portion of the station's solar array panels and a blue and white part of Earth provide the backdrop for the scene.

The Lab is Open

The mission of the International Space Station (ISS) Program is to advance science and technology research, expand human knowledge, inspire and educate the next generation, foster the commercial development of space and demonstrate capabilities to enable future exploration missions beyond low Earth orbit (LEO).

To execute this mission — specifically, technology advancements — the ISS Program is using the space station as a test bed to demonstrate operational techniques and capabilities, and demonstrate technologies and advanced systems that benefit space science capabilities and human and robotic exploration beyond LEO. Working with the international exploration community, the Global Exploration Roadmap was developed to provide an internationally, phased approach defining capabilities that will be needed for future exploration. Demonstration of these advanced capabilities is a primary objective of the ISS Program mission.

This booklet has been developed to provide prospective technology and advanced system developers the information that will aid in the formulation of demonstration concepts and as an introduction of station capabilities, characteristics and processes.

The following pages begin by describing the technology development areas of greatest interest to the National Aeronautics and Space Administration (NASA) followed by descriptions of ISS interfaces and the manifesting process. Finally, points of contact are identified before a description of the processes and capabilities that are available to selected and manifested payloads.

The Microbial Aerosol Tethering on Innovative Surfaces in the International Space Station (MATISS) experiment investigates the antibacterial properties of materials in space to see if future spacecraft could be made easier to clean. The experiment aims to understand the mechanisms of attachment of biofilms in microgravity conditions.

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ISS Technology Demonstration Program

Overview

The ISS Program provides an infrastructure capable of demonstrating prototypes and systems that may advance spaceflight technology readiness. The space station, the in-orbit crew, the launch and return vehicles, and the operation control centers are all supporting the demonstration of advanced systems and operational concepts that will be needed for future exploration missions.

The ISS is the only long-duration platform available in the relevant space environment with an integrated space systems architecture that can be used to demonstrate advanced technologies and operations concepts. Working in close cooperation with the exploration community, the ISS Program enables technology and systems investigations in support of future exploration endeavors.

The ISS Program aims to demonstrate many types of technologies on the space station where they can be evaluated without significant risk to crew or vehicle in order to accelerate development and reduce risks for future exploration missions.

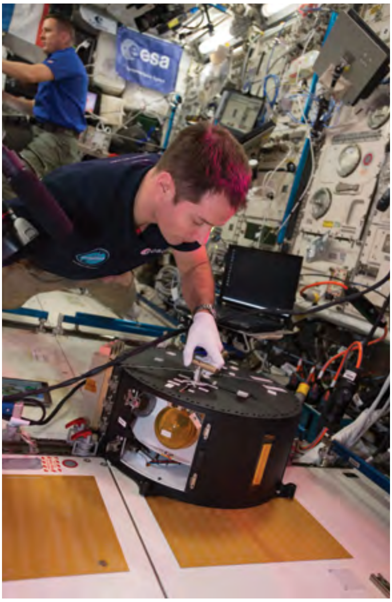
Technology Readiness Level Advancement

The ISS Laboratory is available to conduct research and/or engineering investigations to advance Technology Readiness Levels (TRL) by demonstrating system performance in the unique space environment offered by station or its visiting vehicles. Additionally, station-based demonstrations support proofing concepts of operations, training, crew interfaces, and logistics as well as the

maintainability and reliability of payloads. Performing these demonstrations on the space station provides an opportunity to obtain operational knowledge in a relevant environment without the added costs and risk associated with integrating a new technology or advanced system into an operational system.

In 2020, NASA identified 17 exploration technology areas of interest to enable future space missions and support commercial air travel. Of these 17, ISS can serve as a Technical Demonstation test bed for the following 13 technology areas. Details of exploration and technology needs are documented in the document [2020 NASA Technology Taxonomy].

Propulsion Systems



Systems for in-space propulsion can benefit from in-space demonstration by gaining operational run time in the microgravity, vacuum and thermal environments of space while gaining experience in fuel flow management and performance. Demonstrations providing integrated system operations or subsystem investigations demonstrating supporting elements of a system can be performed.

If scaled to not adversely impact ISS, in-space propulsion systems can be demonstrated on the space station, potentially on visiting vehicles or deployed free fliers.

ESA Astronaut Thomas Pesquet closes out the Fluidics study. ESA's fluid physics investigation may lead to the development of better fuel systems for satellites and provide for longer satellite lifetime by better managing use of fuel for maneuvering.

Flight Computing and Avionics

Flight computing and Avionics is a broad area that covers unique electronics and computing hardware when applied to flight systems. On-board ISS, flight computing and avionics systems can be exposed to the harsh environment of

Deployment of the NanoRacks-Remove Debris Satellite from the International Space Station (ISS) using the NanoRacks Kaber MicroSat Deployer. NanoRacks-Remove Debris aims to demonstrate key technologies for Active Debris Removal to reduce the risks presented by space debris.

space to assess the effects of such factors as extreme heat and cold, high-energy radiation, extreme vacuum, and space debris impact. The knowledge gained through technology demonstrations can inform the development of future computing systems for deep space exploration.

Avionics systems and subsystems are the building blocks for vehicles and spacecraft that implement key functionality for Command and Data Handling, Data Acquisitions, and other essential functions for NASA missions.

Space Power and Energy Storage

The Roll-Out Solar Array (ROSA) is a new type of solar panel that rolls open in space like a party favor and is more compact than current rigid panel designs.

Solar array and solar cell demonstra-tions in space are important because they allow developers to test device performance without the solar filtering and diffusion caused by the atmosphere. At the same time, they provide the appropriate thermal and dynamic loading conditions for an implemented system.

Fuel cells and other systems that operate with fluids, especially two-phased fluids, benefit from demonstrating performance in the microgravity environment.

Robotics Systems

Robotic systems operating in and around a spacecraft, with or without crew-robot interaction, demonstrate performance and operational concepts of robotic systems in the crewed and uncrewed spacecraft environments.

NASA astronaut Megan McArthur poses with the Astrobee robotic free-flyers in support of the Kibo Robot Programming Challenge (Robo-Pro Challenge). The Kibo-RPC allows students to create programs to control Astrobee, a free-flying robot aboard the ISS.

Communication and Navigation

SCAN Testbed installed on ELC 4 nadir side of the ISS.

Communication systems can use the space station infrastructure to demonstrate delay tolerance and eliminate space communication architecture bottlenecks, thus increasing throughput of the integrated systems.

Navigation systems can be demonstrated on ISS, comparing system performance to the spacecraft's known position. Advanced or automated rendezvous and docking systems can be demonstrated with ISS and visiting vehicles or dedicated free fliers. (See also Guidance, Navigation, and Control)

Human Health, Life Support, and Habitation Systems

The Capillary Structures for Exploration Life Support investigation studies water recycling and carbon dioxide removal using structures of specific shapes to manage fluid and gas mixtures, benefiting future efforts to design lightweight, more reliable life support systems for future space missions.

The job of maintaining a habitable environment for the crew over the duration of a human spaceflight mission is performed by Environmental Control & Life Support Systems (ECLSS). Living in space for long durations with little or no resupply from Earth is a fundamental capability that is being matured through day-to-day operations on the only platform capable of that task – ISS. For long-duration exploration beyond LEO, spacecraft systems must provide a stable, self-contained micro-environment around the clock by revitalizing the air, collectingand processing wastewater streams to recover and provide safe drinking and hygiene water for the crew, and managing solid wastes (metabolic and trash). ISS presents the opportunity to perform limited upgrades to the current systems to increase operational availability and reduce system mass, consumables and power needs beyond the current capability. At the same time, ISS provides a directly relevant operating environment to perform demonstrations of technologies and prototype systems to reach capabilities necessary to enable an exploration-class mission.

Operational demonstrations aboard ISS will ensure that the ECLSS needed for exploration beyond LEO has been verified properly to keep the crew alive and safe for more than a year away from Earth.

Exploration Destination Systems

Human Exploration Systems are exploration-specific capabilities that do not clearly fall into other technology categories. As such, the technologies in this area are diverse and expansive. Many of these technologies are related to extravehicular activity (EVA), or spacewalks, and general habitation. These systems can benefit from the microgravity environment and utilization within the operation of the station-habitable environment.

Sensors and Instruments

The Biomolecule Sequencer for the BEST experiment demonstrated the feasibility of DNA sequencing in an orbiting spacecraft. A space-based DNA sequencer can identify microbes, diagnose diseases, understand crew member health, and potentially help detect DNA-based life elsewhere in the solar system.

As advances in scientific technology enable more capable science and sensor systems, prototype systems can be demonstrated on ISS to evaluate performance in the space environment and in relevant conditions. On ISS, these systems can be evaluated by the in-orbit crew or within the existing station commanding and data infrastructure, such that confidence can be gained and risks reduced in the system before it is used on a dedicated science mission. Additionally, science system demonstrations can be used to evaluate and assist in choosing among systems that are under consideration.

Entry, Descent, and Landing Systems

ISS visiting vehicles re-enter Earth's atmosphere following station-docked missions. There are several methods to deploy small

The Cygnus NG (Northrop Grumman) cargo spacecraft is pictured in the grips of the Canadarm2 robotic arm. Cygnus would be released moments later as the ISS orbited over the Pacific Ocean. Visible in Cygnus' Common Berthing Mechanism is the Slingshot small satellite deployer designed to deploy CubeSats from the cargo ship once it reaches a safe distance from the station.

satellites from the space station that will re-enter the atmosphere. These opportunities can be used to demonstrate capabilities and techniques and increase knowledge of atmospheric re-entry.

Autonomous Systems

Seeker, an automated extravehicular free-flying inspector CubeSat, and its communication link, Kenobi. The primary objective of the Seeker mission is to demonstrate a path toward an inspection capability for future crewed space missions.

The definition of Autonomous Systems varies widely depending on the discipline. In the context of this booklet, it is defined as stated in the 2020 NASA Technology Taxonomy: An autonomous system (in the context of robotics, spacecraft, or aircraft) is a cross-domain capability that enables the system to operate in a dynamic environment independent of external control.

In general, ISS serves as a test ground for technology demonstrations that aim to reduce the crew's dependence on ground-based mission control and support. Under microgravity conditions, NASA's sponsors and partners can test autonomous concepts such as systems anomaly detection, precursor detection, issue detection and isolation, augmented reality (AR), autonomous medical skill and & decision support systems, in-flight autonomous logistics, fault diagnosis and prognosis, among many others.

Materials, Structures, Mechanical Systems, and Manufacturing


View of Materials on ISS Experiment - 8 (MISSE-8) installed on the starboard truss. Photo taken by Expedition 28 Flight Engineer (FE) Ron Garan during a session of Extravehicular Activity (EVA).

Long-duration exploration missions experience the ultraviolet, thermal and energized particle radiation environment of space requiring the use of materials on spacecraft that can survive these harsh conditions. ISS offers long-duration space exposure for materials evaluation. Space station return vehicles can also be used to expose sample materials being considered for the return environment.

Thermal Management Systems

The STP-H5-Electro-Hydro Dynamics (STP-H5 EHD) investigation demonstrated the long-term operation of a thermal control system on ISS.

Besides re-entry thermal protection, spacecraft thermal technologies are needed to maintain cryogenic systems and thermal control of a spacecraft's systems and internal environment.

Cryogenic systems contain fluids in two-phased regimes. Thermal insulation and recapture, fluid flow, and level measurement of these fluids are uniquely affected by the space and microgravity environment. Demonstrating system capabilities in the relevant environment of ISS would demonstrate needed exploration capabilities.

Heat rejection technology should operate efficiently and reliably across a wide range of thermal environments. Future spacecraft will benefit from advanced technologies and systems that can efficiently maintain heat loads in both the hot and cold environments of space.

Guidance, Navigation, and Control (GN&C)

Guidance, Navigation, and Control (GN&C) is a vast area important to all forms of aerospace systems. Onboard ISS, some facilities are provided specifically to test and demonstrate GN&C capabilities systems such as free flyers and CubeSats. Ultimately, the ISS serves as a microgravity laboratory for technology demonstration of systems that need GN&C testing to complete their design objectives.

ISS Accommodations

ISS provides investigators with a variety of accommodations and resources. Accommodations include internal or pressurized habitable volume, external exposure to the space environment, transportation to and from the space station, and deployable options.

A few of the accommodations more commonly utilized by technology demonstration payloads are highlighted here. For a more comprehensive description of the facilities and accommodations on ISS, the reader is referred to the International Space Station Facilities Book.

Internal

Internal to ISS, the technology and system demonstrations will be exposed to the nominal habitable station environment.

Expedite the Processing of Experiments for Space Station (EXPRESS) Racks

Internal to the space station habitable volume, technology demonstrations can be installed in the EXPRESS racks. EXPRESS racks support multi-discipline investigations and provide several resources that can be utilized in the technology demonstration.

EXPRESS Rack Resources

System	ISS Locker Locations	ISIS Drawer Locations	Rack-Level Accommodations
Structural	Volume: 2 cubic feet Internal Dimensions: 20.32 x 17.34 x 9.97 inches	Volume: 1.26 cubic feet Internal Dimensions: 23.25 x 16.62 x 6.0 inches	8 ISS Lockers 2 ISIS Drawers (4 Panel Unit)
Power	28 Vdc, 0 - 500 W	28 Vdc, 0 - 500 W	2000 Watts 28 Vdc power
Air Cooling	< 200 Watts	< 100 Watts	1200 Watts
Thermal Control System Water Cooling	500 Watts (2 positions per rack)	500 Watts (2 positions per rack)	2 positions per rack
Command & Data Handling	RS422 Analog Ethernet 5 Vdc Discrete Ethernet 802.3* WiFi Ethernet 802.11b/g*	RS422 Analog Ethernet 5 Vdc Discrete Ethernet 802.3* WiFi Ethernet 802.11b/g*	RS422 Analog Ethernet 5 Vdc Discrete Ethernet 802.3* WiFi Ethernet 802.11b/g*
Video	NTSC/RS170A SDI or HDI via JSL-based encoder*	NTSC/RS170A SDI or HDI via JSL-based encoder*	NTSC/RS170A SDI or HDI via JSL-based encoder*
Vacuum Exhaust System	1 payload interface per rack	1 payload interface per rack	1 payload interface per rack
Nitrogen	1 payload interface per rack	1 payload interface per rack	1 payload interface per rack

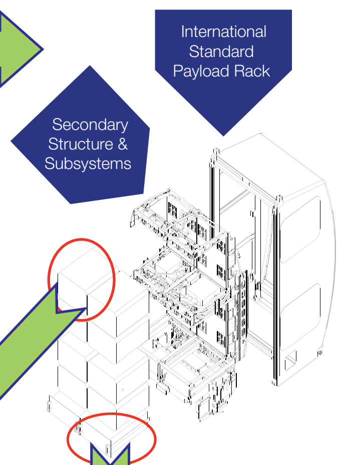
*Table Notes: * These interfaces may require unique hardware and software to enable their use.*

EXPRESS Rack

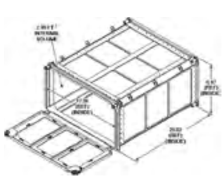
Subrack-size payload capability with standard utilities such as power, data, cooling and gases

EXPRESS 8/2 Configuration

8/2 Payload Configuration
(8 ISS Lockers,
2 Powered ISIS Drawers)



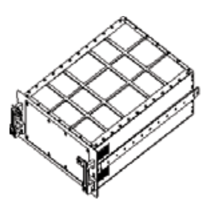
ISS Locker



Features

- 4 rear captive fastener attachments
- Friction hinge
- Dual door locks
- Installation tool guides on 4 corners
- Weight – 12 lbs

International Sub rack Interface Standard Drawer



Features

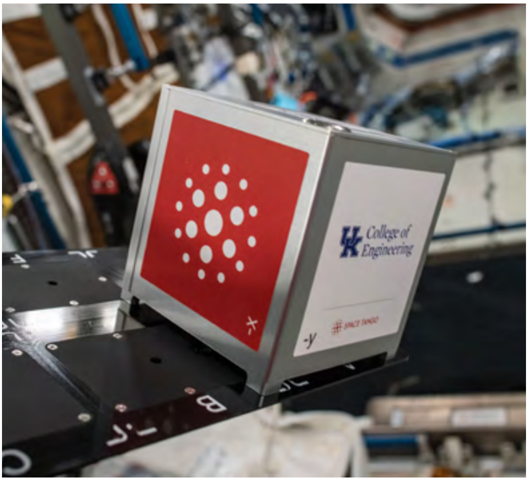
- 4 PU (Panel Unit)
- Blind Connectors
- Locking Handles
- Weight – 27 lbs
- Rated to at least 37 lbs

Station-to-Internal-Facility Rack Resources

The resources listed below are available in various rack locations on ISS.

POWER	3, 6 or 12kw, 114.5-126 voltage, direct current (VDC)	
DATA	Low Rate	MIL-STD-1553 bus 10 Kpbs
	High Rate	100 Mbps
	Ethernet	10/100*/1000* Mbps
	Video	NTSC, SDI or HDI via JSL-based encoder*
GASES	Nitrogen	Flow = 0.1 kg/min minimum; 517-827 kPa nominal; 1379 kPa, maximum
	Argon, carbon dioxide, helium	517-768 kPa nominal; 1379 kPa, maximum
COOLING LOOPS	Moderate Temperature	16.1ºC – 18.3ºC
	Flow Rate	0 – 45.36 kg/h
	Low Temperature	3.3ºC – 5.6ºC
	Flow Rate	233 kg/h
VACUUM	Venting	10-3 torr in less than 2h for single payload of 100 L
	Vacuum Resource	10-3 torr (to maintain vacuum only, not for venting)
*Table Notes: * These interfaces may require unique hardware and software to enable their use.*		

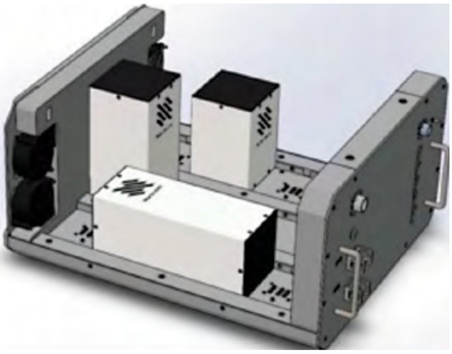
Aisle-Deployed Payloads



In some cases, small technology demonstrations can be installed or demonstrated outside of racks in a manner that does not interfere with crew passage or operations. In these instances, power and data resources can be provided to a payload from an EXPRESS Rack.

This cube containing Space Tango - Cubelab Satellite Demonstrator was part of TangoLab Mission-25.

Nanoracks Nanode and Nanolabs



NanoRacks Nanode (Mainframe) Payload Accommodations

The Nanoracks Nanode is a commercial facility that interfaces between individual Nanolab Modules and the ISS, providing mechanical mounting points and electrical connections for power, data, and communication capabilities. Each Nanode platform is installed in its own EXPRESS rack locker. The Nanoracks Nanode Assembly with Nanolabs (payloads) installed is shown in the figure to the left.

The Quest Institute-NanoLab Unit 3 contains 15 Nanolab experiments from students in the United States and Singapore.

Nanolabs are payloads that can be developed in varying sizes to meet science needs. The Nanode payload interface is designed to accommodate up to 12 standard Nanolab Modules. Nanolab modules longer than 2U (20 cm) and up to 4U (40 cm) in length can be accommodated by laying horizontally in a retention slot and covering multiple connector positions. Other possible non-standard payload sizes can be assessed/considered for Nanode if they do not exceed the overall size of the payload volume. Any non-standard size will require additional evaluation and approval by Nanoracks.

Example Nanolabs

ISS Cold Stowage

NASA's vision for humans pursuing deep space flight involves the collection of science in low earth orbit aboard the International Space Station (ISS). As a service to the science community, Johnson Space Center (JSC) has developed hardware and processes to preserve collected science on the ISS and transfer it safely back to the Principle Technologists. Cold Stowage consists of hardware, both active and passive, that transports science to/from the International Space Station (ISS).

The Cold Stowage team is part of the International Space Station (ISS) program. JSC manages the operation, support and integration tasks provided by Jacobs Technology and the University of Alabama Birmingham (UAB). Cold Stowage provides controlled environments to meet temperature requirements during ascent, on-orbit operations, and return, in relation to International Space Station Payload Science.

ISS Passive Cold Stowage Accommodations

Double Coldbags (DCBs) have highly insulated walls and are designed to carry payload science at controlled temperatures by using Phase Change Material (PCM) to maintain specific temperatures for a prolonged period of time. The DCB is rectangular and fits in a single ISS locker. It is commonly used to transport science to and from the ISS on visiting vehicles.	
Mini Coldbags (MCBs) are similar to DCBs but are significantly smaller. This coldbag has been optimized for return on a Soyuz vehicle. The MCB can also be used within a Glovebox as a means to immediately begin cooling samples after collection.	
Ice Bricks are designed to provide cooling or incubation to scientific specimens requiring specific temperature ranges during transport to/from the ISS. They are designed to work with other insulated transporters (e.g. DCB, MCB) to maintain specific temperatures between -32°C and +37°C. Ice Bricks are reconditioned using active hardware (MELFI, Glacier, Polar, MERLIN).	

ISS Cold Stowage Active Hardware

The Minus Eighty degree Laboratory Freezer for the International Space Station (MELFI) is a refrigerator/freezer used to preserve science samples on the ISS. MELFI has four insulated dewars which can be set independently to +2°C, -35°, or -95°C.	
MERLIN is a single ISS locker-sized incubator/fridge/freezer. The primary functions of MERLIN are to provide temperature-specific environments for samples aboard ISS and thermal control in visiting vehicles. MERLIN is designed to support experiments requiring temperatures between +4°C and +40°C for launch/return, and -20°C to +48°C on ISS.	
The Glovebox Freezer and Cryo Chiller provide the capability to rapidly freeze science samples at rates approaching those of Liquid Nitrogen on the ground. Samples are frozen via a conduction interface at -185°C. A "sample cartridge" provides the conduction interface for science samples when inserted into either the Glovebox Freezer or Cryo Chiller.	
The Cryo-Chiller is a single ISS locker-sized freezer that supports experiments at -160°C for launch and return in addition to on orbit rapid freeze operations.	
The Glacier is a double ISS locker-sized cryogenic freezer. The primary function of Glacier is to provide cryogenic preservation of science samples aboard the ISS and thermal control in visiting vehicles. Glacier is designed to support experiments that require temperatures between -95°C and +4°C for launch/return and –160°C to +4°C on ISS.	

Other Internal Tools

NanoRacks Microscope-3 is an off-the-shelf Universal Serial Bus (USB) microscope. Image courtesy of NanoRacks LLC.

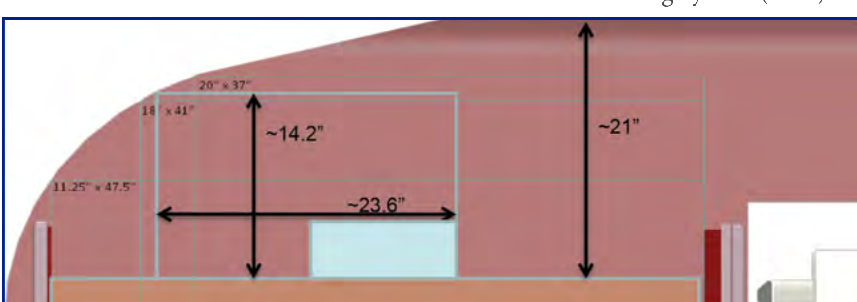
Nanoracks has optical and reflective microscopes available for commercial use with digital image retrieval for ISS experiments. A Nanoracks Plate Reader is also available to monitor samples in microtiter plates with 96 wells with controls for temperature and stirring.

The Nanoracks Microscopes facility includes three commercial off-the-shelf optical and reflective microscopes. They use plug-and-play USB technology and allow crew members to analyze and digitally transfer images of ISS in-orbit samples.

Airlock Options

Japanese Experiment Module (JEM) Airlock

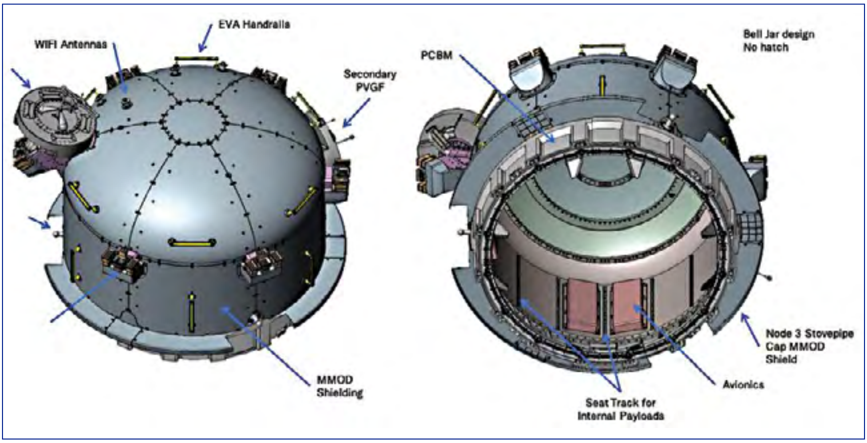
The JEM has an equipment airlock that allows the transfer of payloads between the internal pressurized cabin and space. Payloads attach to a slide table that extends into the cabin for crew access or extends out the JEM Exposed Facility for access by either the JEM robotic arm or the Mobile Servicing System (MSS).



The JEM arm or MSS moves the payload between the JEM airlock and external ISS locations. The JEM airlock can accommodate a payload up to 300 kg in mass that fits within the dimensions of the airlock. The general dimensions and form of the airlock volume are shown above and are 32 inches in width. JEM airlock usage is negotiated on an as-needed basis.

Bishop Airlock

The Nanoracks Bishop Airlock is a commercial airlock that offers an array of different capabilities. From microsatellite deployment to externally hosted payloads to microgravity experiments, the Bishop Airlock can accommodate a variety of large or small payloads with unique pointing possibilities. The Bishop Airlock is attached to the Node 3 Port berthing ring.

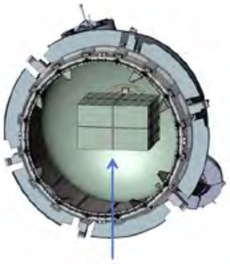


Bishop Airlock Satellite Deployment Nominal Payload Envelope

- Maximum payload size 44.2” x 44.2” x 50” and 709 lbs
- Must fit through Node 3 Hatch
  – 46” if CPAs are rotated and kick-plate installed (nominal)
  – 50” if CPAs are removed (premier)
- Maximum 144U per Airlock sortie
- Various satellite sizes can be hosted during one sortie. Can combine CubeSat deployer with multiple MicroSats.

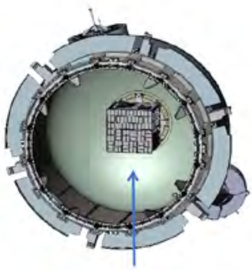
Deployment commands are operated by the Nanoracks Operations Team.

The Bishop Airlock can accommodate multiple options for deploying various payload sizes. Examples are shown below.

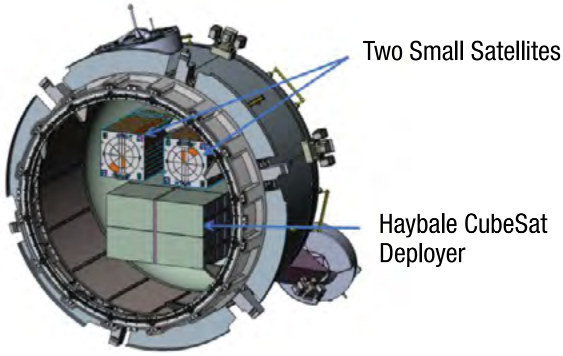


Nanoracks “HayBale” Deployable Cubesat Dispenser (144U capability in configuration shown)

HayBale is deployed from Bishop in similar fashion to ESPA/Kaber-class satellites, using Nanoracks Separation System or Lightband. As “HayBale” is separated from ISS, the orbiting “HayBale” deploys pairs of cubesats over time until deployments are complete. Empty “HayBale” orbit degrades and “HayBale” is destroyed upon re-entry.



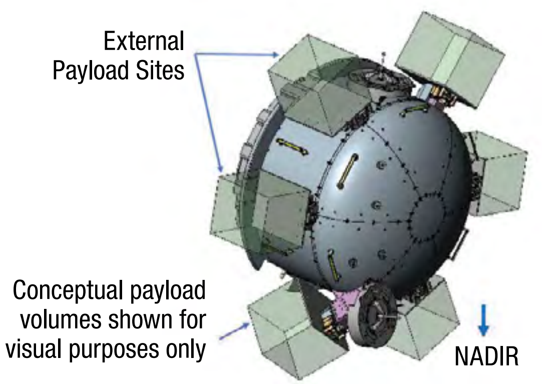
Representative MicroSat (~65kg). This is the max size that can go through JEM Airlock. Bishop can fit up to four of these satellites in at one time.



Pressurized or unpressurized launch opportunities are available. Oceaneering GOLD 2 connector provides electrical, mechanical and robotic interface. Infinite pointing options are available while on the SSRMS (CanadaArm) – including Ram, Wake, Zenith, and Nadir.

Accommodations for Hosted Payloads

The Bishop Airlock has six external payload sites to provide long duration research external to the ISS.



Nominal Payload Envelope:

- 500 lbs (227 kg)
- Exceedances may be considered on a case-by-case basis

Power: 120 VDC; 350 watts (nominal)

- Maximum 700 watts but must coordinated with Nanoracks: total Airlock payload power available is 2.6 kW berthed and 1.8kW un-berthed, Payload usage of this shared resource is managed by Nanoracks.

Data: Ethernet protocol (nominal)

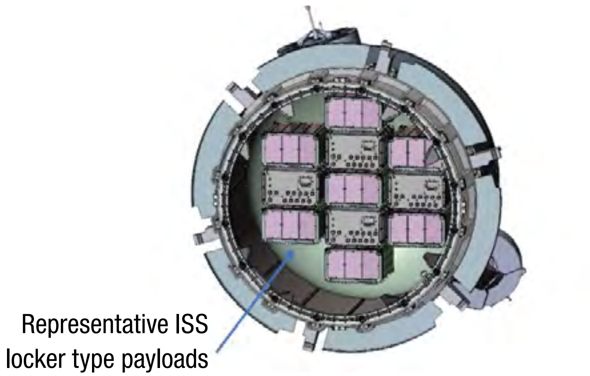
- 100 Mb/sec to Airlock avionics
- Data rate from Airlock to ISS: 100 Mb/sec berthed (hardwired to Node 3); 10 Mb/sec un-berthed (WIFI)
- Data rate to ground to be negotiated with NASA
- Data storage capability within Airlock avionics

Redundant power and data interfaces

- Redundant fiber optics and coaxial connections also available and terminated inside of Airlock pressure shell

Accommodations for Microgravity Research

In addition to the externally hosted and satellite deployments, the Bishop Airlock also has the capability to accommodate pressurized microgravity research within the Bishop Airlock while attached to Node 3 Port location.



Nominal Payload Envelope

- Maximum payload size 44.2” x 44.2” x 50” and 709 lbs
- Must fit through Node 3 Hatch
  – 46” if CPAs rotated and kick-plate installed (nominal)
  – 50” if CPA’s removed (premier)

Power: 120 VDC; 350 watts (nominal)

- Maximum 700 watts but must coordinated with Nanoracks as total Airlock payload power available is 2.6 kW berthed and 1.8kW un-berthed – This is a shared resource so payload usage will be managed by Nanoracks.

Data: Ethernet protocol (nominal)

- 100 Mb/sec to Airlock avionics
- Data rate from Airlock to ISS: 100 Mb/sec berthed (hardwired to Node 3); 10 Mb/sec un-berthed (WIFI)
- Data rate to ground to be negotiated with NASA
- Data storage capability within Airlock avionics

Operations conducted by in the Nanoracks “Bridge” in coordination with NASA, crew, and customer.

External

ISS provides a variety of external sites and services to conduct payload investigations.

EXPRESS Logistics Carrier (ELC)

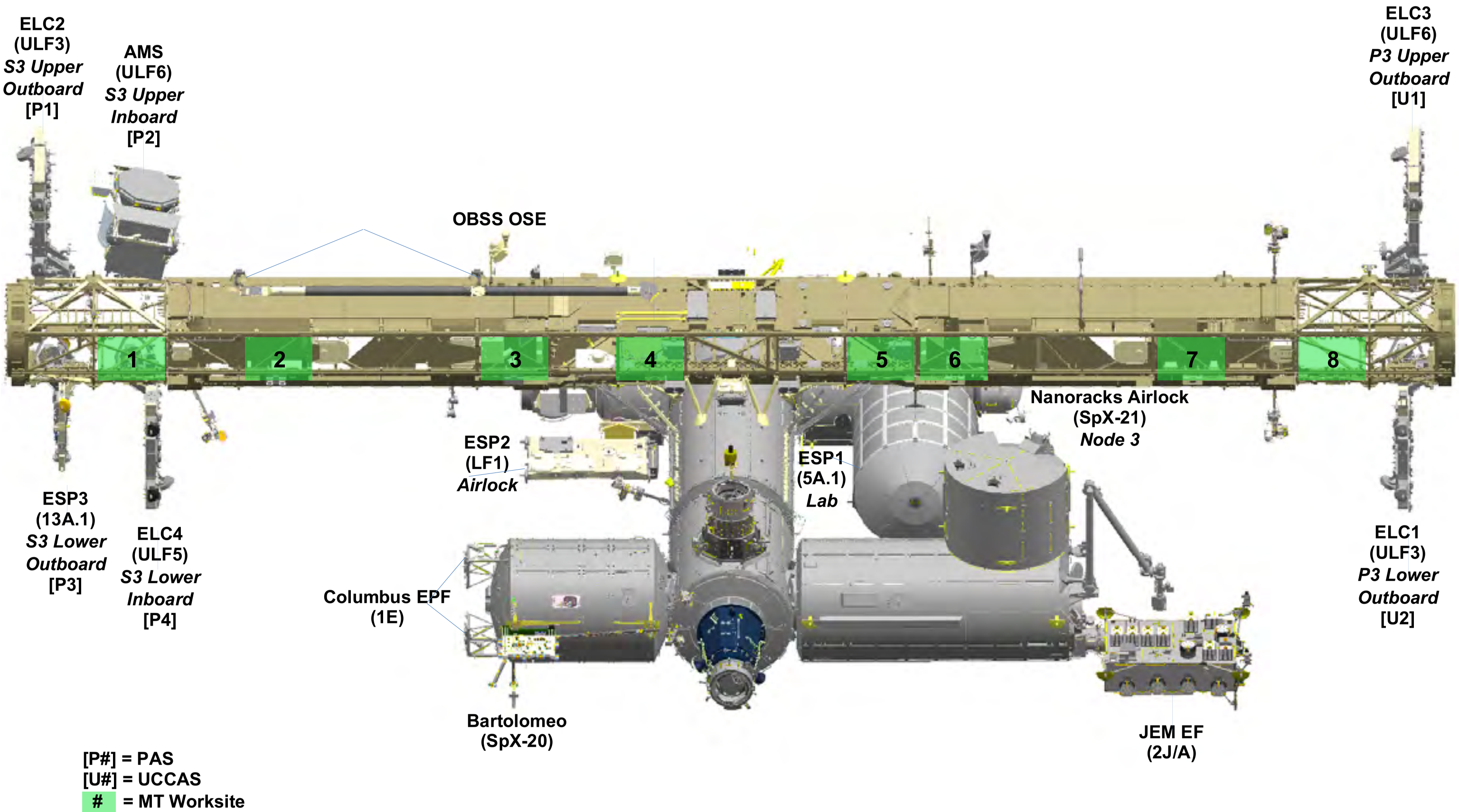
Technology demonstrations performed externally on ISS can be attached to one of the ELCs. The ELC locations offer viewing options ranging from nadir to zenith and points in between. Payload demonstrations attaching to the ELC will require the use of a Flight Releasable Attachment Mechanism (FRAM). The FRAM provides mechanical, electrical, thermal, data, EVA, and robotic interfaces to ISS.

ELC External Research Accommodations

Mass capacity	227 kg (500 lb)
Volume	1 m^3
Power	750 W, 113 – 126 Vdc; 500 W at 28Vdc per adapter
Thermal	Active heating, passive cooling
Low-rate data	10 Kbps (MIL-STD-1553)
Medium-rate data	6 Mbps (shared)
Wi-Fi Ethernet*	100 Mbps (shared)
Sites available per ELC	2 Sites
Total ELC sites available	8 Sites
*Table Notes: *These interfaces may require unique hardware and software to enable their use.*	

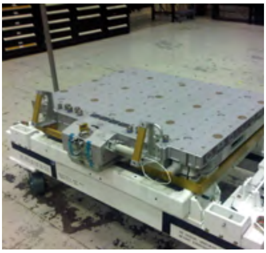
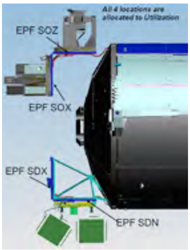
The medium rate data interface will be updated at each ELC location to 100 Mbps two-way wireless LAN.

ISS Attach Sites



Columbus Exposed Facility (EF)

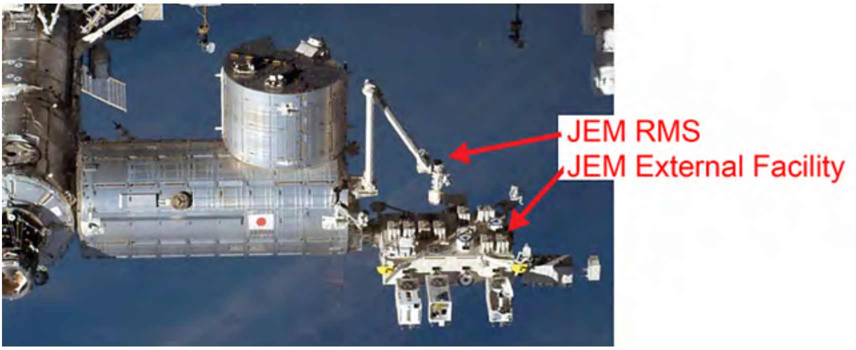
Located on the starboard side of space station, the ESA (European Space Agency) Columbus module also provides an external facility to accommodate external technology demonstrators. Similar to the FRAMs, the technology demonstration payload will be provided a Columbus External Payload Adapter (CEPA) to interface to the space station services.

Columbus EF Resources

Location	Viewing	Payload Size	Power	Data
SOZ	Zenith	226kg +CEPA	1.25 kW at 120VDC	1553 -1 Mbs
SOX	Ram		2.5 kW max	ethernet - up to 10 Mbs
SDX	Ram			
SDN	Nadir			

JEM Exposed Facility (JEM-EF)



On the port side of ISS, the JEM provides accommodations for attaching external payloads. The JEM-EF is a multipurpose experiment platform where various investigations/demonstrations can be performed. The JEM-EF has 12 attachment ports for external payload and can accommodate up to ten payloads simultaneously.

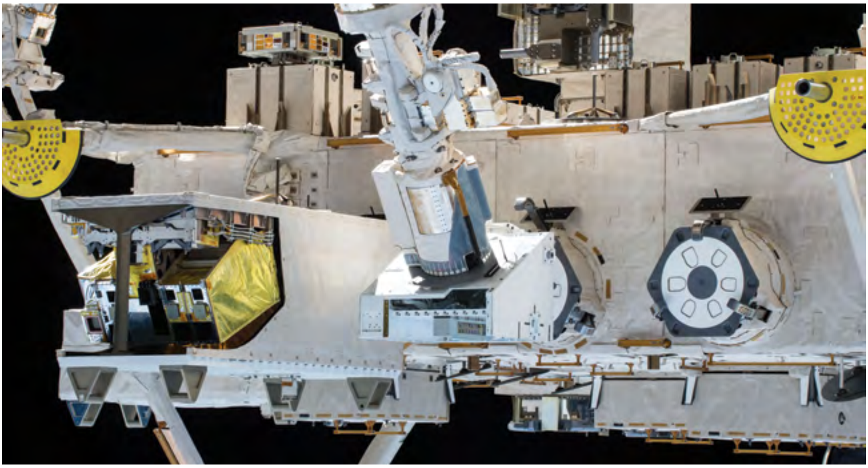
The attachment port on the JEM-EF provides mechanical, thermal and electrical interfaces to the attached payloads. This interface mechanism is called Experimental Exchange Unit (EEU).

JEM External Resources

Mass Capacity	550 kg (1150 lb) at standard site 2250 kg (5550 lb) at large site
Volume	1.5 m^3
Power	3 – 6 kW, 113 – 126 Vdc;
Thermal	3 – 6 kW cooling
Low-rate data	10 Mbps (MIL-STD-1553)
High-rate data	43 Mbps (shared)
Wi-Fi Ethernet*	100 Mbps (shared)
Sites available to NASA	5 Sites
*Table Notes: *These interfaces may require unique hardware and software to enable their use.*	

NanoRacks External Platform (NREP)

NanoRacks External Platform is the first commercial research capability for testing science investigations, sensors, and electronic technologies in space. The NREP is located on the JEM-EF, and payloads are deployed by the Japanese Experiment Module Remote Manipulator System (JEMRMS).



The Japanese Experiment Module Remote Manipulator System (JEMRMS) moves to install the NanoRacks External Platform (NREP) on the JEM (Japanese Experiment Module) Exposed Facility (JEF).

External Platform Hosting Features

Location: JEM External Facility (ISS)
Form Factor (Active): Five 4U locations
Form Factor (Passive): Four 3U locations
Payload Volume: 32U total
Pointing: Nadir
Mission Lifetime: 15 weeks (nominal), extension optional
Maximum Capacity: 35 kg (1 kg/U mass allocation)
Power: 28 VDC (30W nominal, 50W max per payload)
USB Power: 5 VDC, 500mA
Nominal Turnover: L-3 Months

Non-standard services and accommodations:

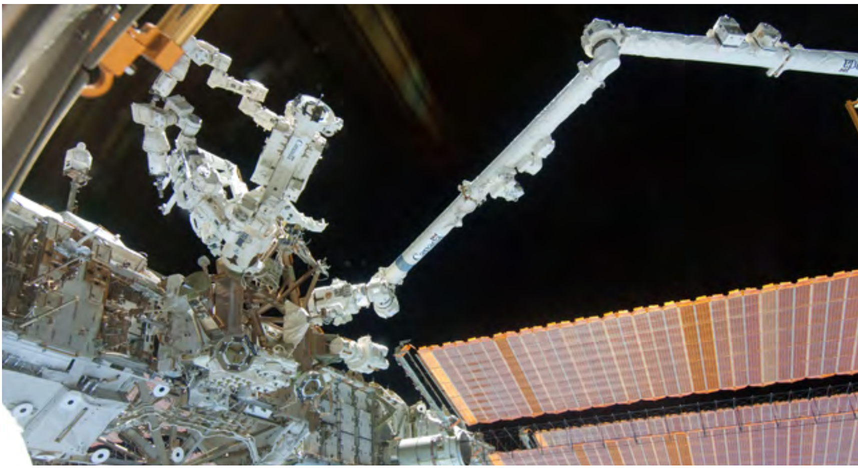
- Extended mission duration
- Additional power
- Additional data services
- Non-standard form factors

Robotic Capabilities

EVAs (spacewalks) at ISS are reserved to address critical maintenance activities. With limited spacewalk opportunities, external technology demonstration payloads must be robotically manipulated and installed. Currently, there are two robotic manipulator systems aboard ISS. These robotic systems were responsible for much of the construction of the space station and are now available for payload utilization.

Mobile Servicing System (MSS)

The MSS is part of the Canadian Space Agency's contribution to ISS. It consists of the Space Station Remote Manipulator System, the Special Purpose Dexterous Manipulator, and the Mobile Base System. These, along with two robotics workstations, to operate the robotic systems from inside the space station, and the Mobile Transporter, which is used to transfer hardware along the length of the truss, are now assisting with payload utilization.



In this image, the Canadian-built Dextre, also known as the Special Purpose Dextrous Manipulator (SPDM), is at top left. The station's Canadarm2 is also featured.

JEM Robotic Manipulator System (RMS)

The JAXA-provided RMS resides on the JEM-EF. This manipulator can be used to remove payloads from the JEM airlock for placement on the EF and can also be used with ISS small satellite deploying systems to launch deployable payloads.

Access to the External Environment

Payloads can gain access to the external environment in one of two ways. For large payloads that are destined for one of the payload accommodation sites, they can be launched to ISS inside the SpaceX Dragon Trunk. Once the Dragon has been captured and berthed to the space station, the MSS can be used to remove the payload and install it at its destination. Smaller payloads can be launched to ISS in the pressurized environment in one of the many launch vehicles and then transferred to the space environment through JAXA's JEM airlock.

Robotic Interfaces

FRAMs and CEPAs are provided to technology payload developers as Government Furnished Equipment. Robotic interfaces are pre-integrated with the FRAMs and CEPAs.

Special Considerations

Special consideration should be given to externally-attached demonstration payloads in the following areas:

Contact Loads - Payloads that are maneuvered with a robotic manipulator are generally moved into and out of areas of tight clearance with station hardware. While every effort is made to prevent collision, there are some unpredictable failure cases where contact may occur. Ideally, payloads should be designed to withstand the energy imparted from this inadvertent contact.

Thermal Environment - In an effort to preserve as much in-orbit crew time as possible, a majority of in-orbit robotic operations are performed by ground controllers from the Mission Control Center (MCC). Applied constraints on the ground-controlled robotic motion can result in a long-duration transit to the payload's destination. Given the thermal extremes that can be experienced during this timeframe, a payload developer should consider this when designing a payload's thermal control system.

Deployable Small Satellites

ISS has limited capability to deploy small satellites from the space station for free flight and ultimate re-entry to Earth's atmosphere.

Platform	Size, Approximate mm (Inches)	Mass (Max, of Deployed satellite)	Location of Deployment
J-SODD	1U - 100 x 100 x 113.5 mm (3.9 x 3.9 x 4.7 inches) 2U - 100 x 100 x 227.0 mm (3.9 x 3.9 x 8.9 inches) 3U - 100 x 100 x 340.5 mm (3.9 x 3.9 x 13.4 inches)	1.33 Kg/1U	Deployed from ISS (JEM EF)
CYCLOPS	1117.6 x 762 x 279.4-533.4 mm (44L x 30W x 11-21H inches)	100 kg	Deployed from ISS (JEM EF)
Space X	1U - 100 x 100 x 100 mm (3.9 x 3.9 x 3.9 inches) 2U - 100 x 100 x 200 mm (3.9 x 3.9 x 6.8 inches) 3U - 100 x 100 x 300 mm (3.9 x 3.9 x 10.7 inches)	1.33 kg/1U	Deployed from Space X prior to ISS docking

Platform	Size, Approximate mm (Inches)	Mass (Max, of Deployed satellite)	Location of Deployment
SEOPS Slingshot	1U – 119 x 119 x 100 mm 2U – 119 x 119 x 227 mm 3U – 119 x 199 x 366 mm 6U – 119 x 245 x 366 mm 12U – 245 x 245 x 366 mm Optional tuna can is 88 mm max diameter, 46 mm long	1U – 2.0 kg 2U – 4.0 Kg 3U – 6.0 kg 6U – 12.0 kg 12U – 24.0 kg	Deployed from Cyngus, post unberth from ISS Note: Slingshot is compatible with both rail / tab formats.
Nanoracks CubeSat Deployer (NRCSD)	1U - 100 x 100 x 113.5 mm (3.9 x 3.9 x 4.7 inches) 2U - 100 x 100 x 227.0 mm (3.9 x 3.9 x 8.9 inches) 3U - 100 x 100 x 340.5 mm (3.9 x 3.9 x 13.4 inches) 4U – 100 x 100 x 454.0 mm (3.9 x 3.9 x 17.8 inches) 5U - 100 x 100 x 567.5 mm (3.9 x 3.9 x 22.3 inches) 6U-100 x 100 x 681-740 mm (3.9 x 26.8 - 29.1 inches)	1U – 2.40 kg 2U – 3.60 kg 3U – 4.80 kg 4U – 6.00 kg 5U – 7.20 kg 6U – 8.40 kg	Deployed from ISS (JEM EF)
Nanoracks DoubleWide Deployer (NRDD), Tabs	6U–116.2 x 239.2 x 366 mm (4.5 x 9.4 x 14.4 inches) 12U–116.2 x 239.2 x 732 mm (4.5 x 9.4 x 28.8 inches)	6U – 12.0 kg 12U – 18.0 kg	Deployed from ISS (JEM EF)
Nanoracks DoubleWide Deployer (NRDD), Rails	6U – 100 x 226.3 x 366 mm (3.9 x 8.9 x 14.4 inches) 12U - 100 x 226.3 x 732 mm (3.9 x 8.9 x 28.8 inches)	6U – 12.0 kg 12U – 18.0 kg	Deployed from ISS (JEM EF)
Nanoracks CubeSat Deployer – External (NRCSD-E)	1U - 100 x 100 x 113.5 mm (3.9 x 3.9 x 4.7 inches) 2U - 100 x 100 x 227.0 mm (3.9 x 3.9 x 8.9 inches) 3U - 100 x 100 x 340.5 mm (3.9 x 3.9 x 13.4 inches) 4U - 100 x 100 x 454.0 mm (3.9 x 3.9 x 17.8 inches) 5U - 100 x 100 x 567.5 mm (3.9 x 3.9 x 22.3 inches) 6U (1Ux6U) - 100 x 100 x 681.0 - 740.0 mm (3.9 x 3.9 x 26.8 - 29.1 inches) 6U (2Ux3U) - 100 x 226.3 x 366 mm (3.9 x 8.9 x 14.4 inches) 12U (2Ux2Ux3U) - 226.3 x 226.3 x 366 mm (8.9 x 8.9 x 28.8 inches)	1U – 2.40 kg 2U – 3.60 kg 3U – 4.80 kg 4U – 6.00 kg 5U – 7.20 kg 6U (1Ux6U)– 8.40 kg 6U (2Ux3U)– 12.0 kg 12U (2Ux2Ux3U) – 18.0 kg	Deployed from Cygnus post ISS un-berthing

Platform	Size, Approximate mm (Inches)	Mass (Max, of Deployed satellite)	Location of Deployment
Nanoracks Kaber Microsatellite Deployer	640 x 830 x 1079 mm (25.2 x 32.6 x 42.4 inches)	87.8 Kg	Deployed from ISS (JEM EF)
Nanoracks Bishop Airlock	1122 x 1122 x 1270 mm (44.2 x 44.2 x 50 inches)	321.6 kg	Deployed from ISS (NRAL)

Software and Avionics, ISS Command and Data Handling

Health and Status Data

Health and status data include all of the parameters needed by the Crew on-orbit and Payload Operations on the ground to ensure that the payload is operating safely and correctly responding to commands. Some payloads, like those that control hazards, use the caution and warning system or are highly sophisticated, will be required to have health and status implemented with the payload.

Broadcast Ancillary Data (BAD)

MIL-STD-1553 System distributes ISS BAD to all payloads Remote Terminals (RTs). BAD data contains most of ISS vehicle information that experiments may need like station location, position and pointing vector information. In addition, the ISS BAD data contains information about the current pressure, temperature and other environmental information data about the space station modules where payloads are located. If there is data a payload needs that is available and not currently in BAD, it is possible to have it added to BAD if the request is made early.

Unique Ancillary Data

Data available from within the Payload Multiplexer De-Multiplexer (PL MDM) that is not present in BAD can be transmitted to the payload via the definition of a unique ancillary data service. When initialized in the PL MDM, this data is transmitted to the payload via the 1553 bus or the Ethernet.

ISS Data Interfaces

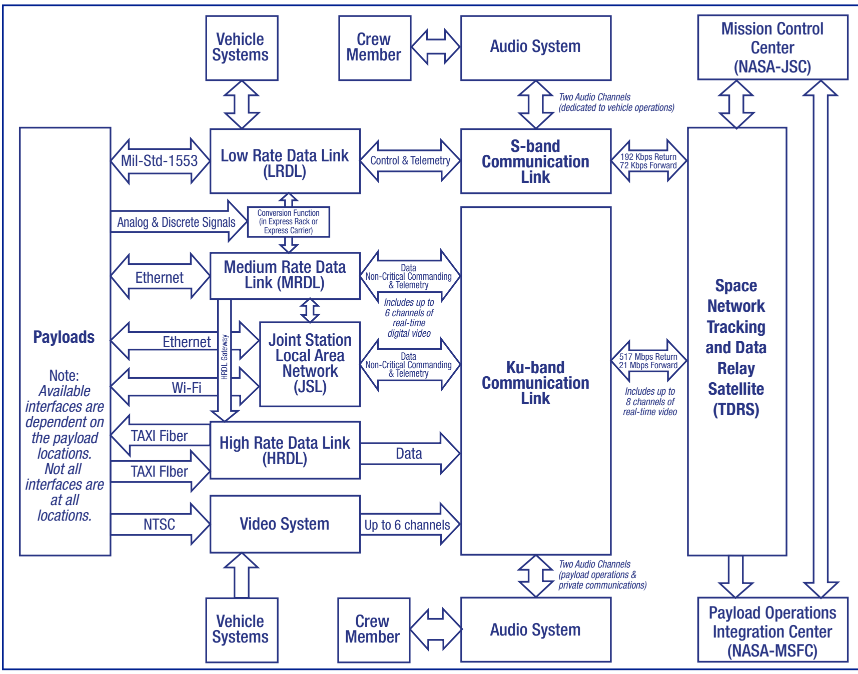
ISS Payload Data Links

Data Interface	Format	Data Rate (1)	Comments
Low Rate Data Link (LRDL)	MIL-STD-1553	10kbps	Nominally used for payload commanding and to gather health and status. Limited telemetry downlink is also available.
Medium Rate Data Link (MRDL)	Ethernet 802.3	10/100Mbps	Ethernet input and output (downlink) available at most internal locations. Downlink via UDP available at most external sites. Not available at external truss sites.
Joint Station LAN (JSL)	Ethernet 802.3	10/100/1000Mbps	Ethernet input and output (downlink) available at most internal locations.
High Rate Data Link (HRDL)	TAXI Fiber-optic	100Mbps	HRDL input and output is available at most internal sites. HRDL available at most external sites.
Video (2)	NTSC	12.5Mbps	Only available at internal International Standard Payload Rack ISPR sites.
Video	SDI or HDI via JSL-based encoder	Configurable (typically 8-12 Mbps)	Available via MRDL or JSL interfaces.
Wireless Data Link	WiFi Ethernet 802.11b/g	100Mbps	Available to internal and external sites that are within range of the access point.

Table Notes: (1) All station data links are shared resources. The data rate listed is the maximum data rate the link can support. (2) Because of the high demand for video downlink and high bandwidth use, it is recommended that the experiments encode and downlink video via MRDL when possible.

The ISS downlink operates at a data rate up to 517 Mbps. The payload users share this bandwidth with ISS system operations (USOS, RS, and visiting vehicles). There are eight real-time downlink video channels and four two-way real-time audio channels. Typically, four video and two audio channels are dedicated to vehicle operations. Live video, two-way audio, and data bandwidth usage is scheduled via coordination with the POIC.

Payload Interfaces to the Communication Links



Data Downlink Availability: Downlink and Storage

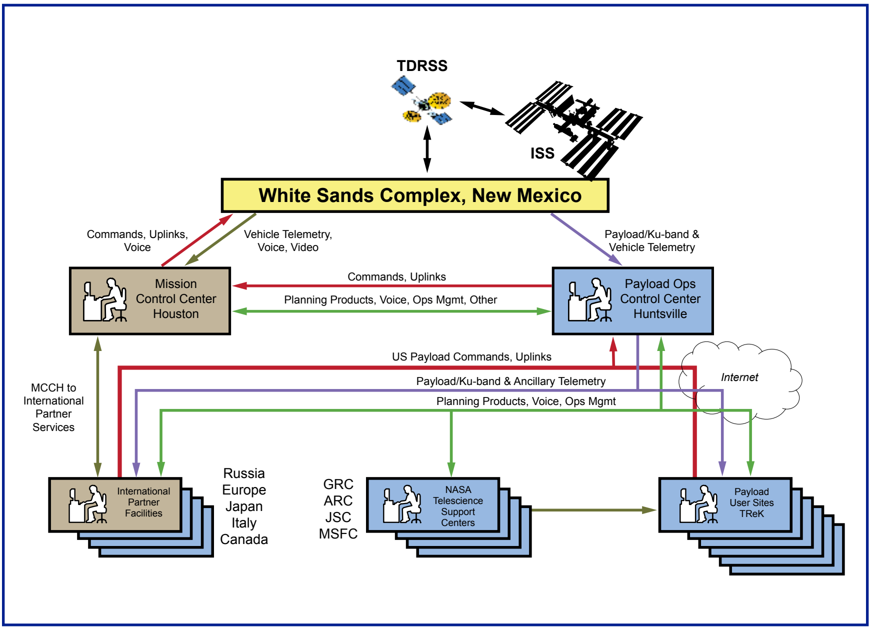
Space Network's Tracking and Data Relay Satellite (TDRS) S-Band and Ku-Band coverage varies based on ISS attitude, location, and beta angle. Typically, coverage ranges from 90-95% on S-band and 80-90% on Ku-band. Payloads should plan to internally store and retain any data essential for the success of the experiment until the principle investigator has verified receipt of the data. Downlinked data is stored by payload operations and can be transmitted to the payload user if they are unable to receive the data when it is downlinked. During loss of signal (LOS) periods between the ISS and TDRS, the Ku-band Integrated Communications Unit (ICU) (1.6 Tbits total storage capability) records payload data that has been designated by POIC for LOS auto-record. The ICU is capable of storing all downlink data for up to a 90-minute LOS period. Upon Acquisition of Signal (AOS), the ICU automatically downlinks ICU-stored data.

Command/Data Latency

During periods of TDRS coverage, the following command uplink and data downlink latencies can be achieved if automatic enabling of payload commanding during Ku-band coverage has been worked out ahead of time with NASA Marshall Space Flight Center Payload Operations Integration Facility:

- Data Downlink Latency, station payload-to-payload developer remote site: 5 sec
- Command Uplink Latency, payload developer remote site to station payload: 10 sec with payload command confirmation, up to 15 sec total.

Data Security and Encryption



Commands and data sent to ISS via S-Band is encrypted at MCC – Houston prior to transmission for security reasons. The ISS does not perform any data encryption on either the Ku-band or S-band downlinks. The payload is responsible for protecting crew health or medically sensitive data or any proprietary data prior to sending it to the ISS data and communication systems for downlink.

Payload Software and Displays

A unique payload software Interface Control Document (ICD) is developed for each payload to document the software and data interfaces. Payloads are required to contain and control all of their hazards internally and are not permitted to use any station C&DH interface or data as a required control of a hazard. Software and firmware used in support of an experiment on ISS must be configuration managed and quality controlled. Software that will need to be uplinked to ISS during the mission must successfully complete NASA's software update and verification process and be virus scanned prior to uplink. At times, software updates must also successfully repeat a vulnerability and penetration set of IT security scans prior to uplink. ISS provides the use of a single fleet of laptops on-orbit. These ISS laptops will be refreshed every few years to stay current with advances in technology. Displays that are to be used by the crew on-orbit in support of an experiment must be delivered to NASA and will be checked for adherence to crew standards and training well in advance of being used on-orbit. The payload software and display implementation plan will be established with the ISSP Program based on the payload type, operational and flight data dependencies, as well as the assigned operational Increment.

Telescience Resource Kit – Payload Operations Interface

The Telescience Resource Kit (TREK) is a suite of PC-based software applications provided to payload developers by the ISS Program that is used by scientists and engineers to monitor and control payloads aboard the space station.

The PC running the TReK software can be located anywhere in the world. This provides a way to monitor and control experiments located on the ISS in the USOS module from their offices and laboratories at home.

TREK can be used to receive payload data from ISS, distributed by the Payload Operations and Integration Center and to perform local data functions such as processing the data, storing it in local files and forwarding it to other computer systems.

Users can extend TREK capabilities by using the TREK Application Programming Interface, together with commercial software products, to utilize local telemetry and command functions.

ISS Characteristics

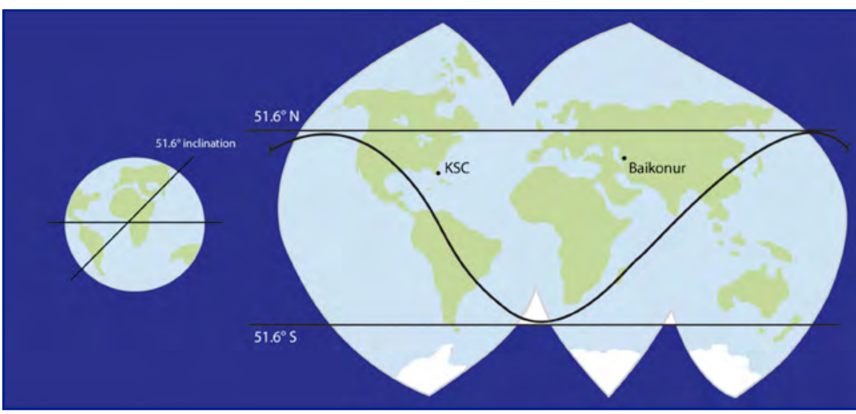
Internal Atmosphere

The nominal station atmosphere is shown in the table below:

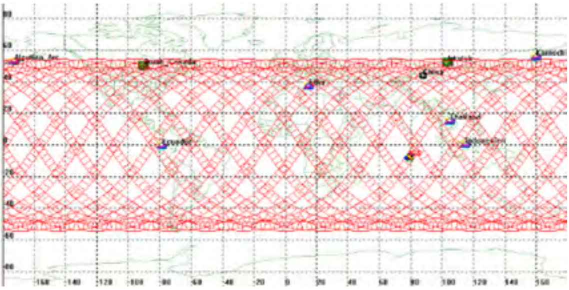
Atmospheric Conditions on ISS	Nominal Value
Pressure	14.7 PSI
Dew point	4.4 to 15.6°C (40 to 60°F)
Carbon dioxide partial pressure	5.3 mm Hg Peak exposure 7.6 mm Hg
Oxygen partial pressure	3.1 PSI ppO_2
Cabin air temperature	17 to 28°C (63 to 82°F)

Orbit Characteristics

Over the course of 72 hours and terrestrial weather conditions permitting, all geographic locations between 51.6 north and south latitude can be observed. ISS provides coverage of 85 percent of the Earth's surface and 95 percent of the world's populated landmass every 1 to 3 days.



The station altitude generally varies with the solar cycle, with the altitude maintained higher during solar maximum. Eccentricity of the station's orbit is maintained at <0.003. In support of visiting vehicles, the altitude is adjusted to accommodate the visiting vehicles' performance parameters. In general, the space station altitude will remain within 395-417 km (245-259 miles).



ISS coverage in 24 hrs for a 70°-swath optical payload. (Courtesy of ESA)

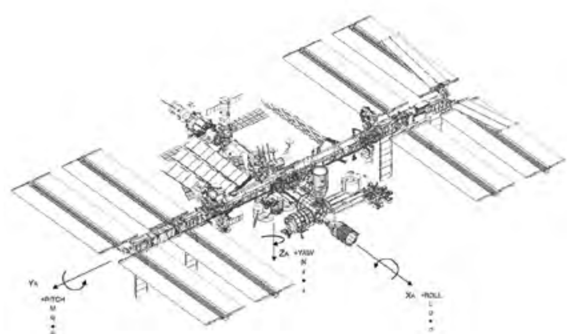
Guidance, Navigation, and Control Characteristics

ISS Attitude Torque Equilibrium Attitude (TEA) & Wobble Oscillation Description – for stage configurations in the foreseeable future (i.e., no orbiter or orbiter-sized vehicles docked on the space station), the predicted TEA ranges are:

Roll: -1.0~+3.0 deg.

Pitch: -7.0~+2.0 deg.

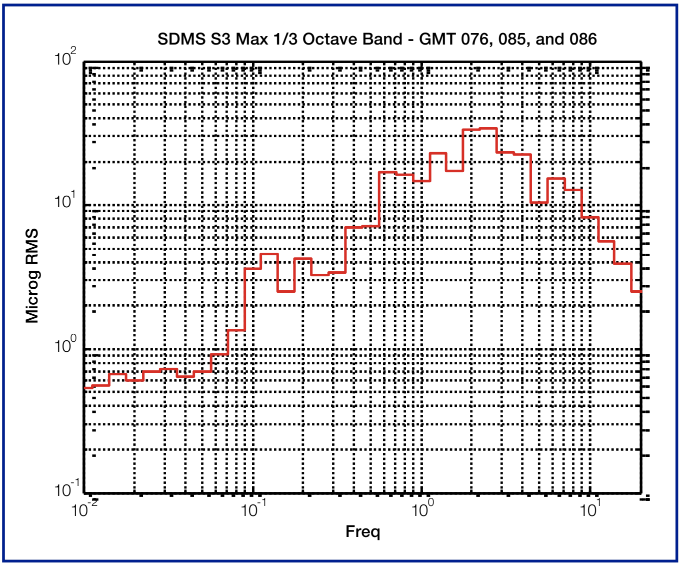
Yaw: -15~+15 deg.



Performance Descriptions	Peak to Peak Attitude Oscillations Per Orbit			Peak Attitude Variation from Steady State Orbit Average Attitude		
	Roll (X) (deg)	Pitch (Y) (deg)	Yaw (Z) (deg)	Roll (X) (deg)	Pitch (Y) (deg)	Yaw (Z) (deg)
Non-Micro-Gravity (Assembly Stages) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement	10.0	10.0	10.0	+/- 5	+/- 5	+/- 5
Micro-Gravity (Assembly Complete) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement	7.0	7.0	7.0	+/- 3.5	+/- 3.5	+/- 3.5
Typical Steady-State Performance of Minimum *CMG momentum oscillation* Momentum Manager Controller	1.6	1.6	2.0	+/- 0.8	+/- 0.8	+/- 1
Typical Steady-State Performance of Minimum *Attitude oscillation* Momentum Manager Controller	1.6	0.4	0.2	+/- 0.8	+/- 0.2	+/- 0.1
Typical Steady-State Performance of Minimum *CMG momentum & Attitude oscillation* Blended Momentum Manager Controller	1.6	0.7	1.2	+/- 0.8	+/- 0.35	+/- 0.6

Microgravity Environment

The following illustration indicates typical observed microgravity characteristics.



Analysis concluded peak ELC rotations on the order of 0.03 degrees per axis (in the quiescent mode).

External Contamination

ISS provides an exceptionally clean environment to external payloads and science assets. External contamination control requirements limit contaminant deposition to 130Å/year on external payloads and station sensitive surfaces.

Specified levels are lower than any previous space station (Mir, Skylab, Salyut) by several orders of magnitude. Measurements of contaminant deposition on ISS-returned hardware have demonstrated that requirements are met at station payload sites.

Experiment	Side	Requirement (130Å/year)	Measured
MISSE 2	ram	520 Å (4 years)	50 Å
	wake	520 Å (4 years)	500 Å
Node 1 nadir window cover	nadir	390 Å (3 years)	50 Å

Transportation to ISS

ISS Cargo Vehicles

Several transport vehicles are available to launch payloads to ISS. When a technology demonstrator becomes a station payload, the ISS Program manifests the payload on the appropriate vehicle. Payload developers do not manifest directly with the launch provider for transport to ISS. Allowable upmass and volume capacities for ISS destination locations are provided below.

SpaceX Dragon Commercial Resupply Vehicle

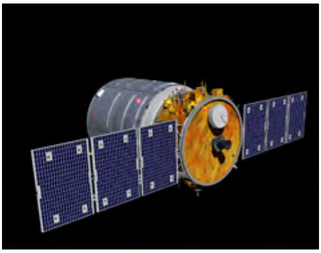
The **SpaceX CRS2 Dragon** vehicle has the capability to launch and dispose of up to 1712kg of Flight Releasable Attachment Mechanism (FRAM), JEM-EF or direct mount unpressurized cargo. The dragon trunk can accommodate up to three FRAM, two JEM-EF, one direct mount or a combination of unpressurized cargo types, depending on the mission-specific manifest. The unpressurized cargo environments can be found in the Cargo Dragon 2 Unpressurized Interface Requirement Documents (IRD).

Sierra Space Dream Chaser Cargo System

The **Sierra Space Dream Chaser Cargo (DCC)** vehicle has the capability to launch and dispose of a total unpressurized cargo complement up to 1500kg of FRAM, JEM-EF or direct mount unpressurized cargo. The DCC Cargo Module (CM) accommodates up to three unpressurized cargo items ranging in size and mass, depending on the mission-specific manifest. The unpressurized cargo environments can be found in the CM to Unpressurized IRD.

JAXA HTV-X Cargo System

The **JAXA HTV-X** vehicle has the capability to launch and dispose of a total unpressurized cargo complement up to 1750kg of FRAM, JEM-EF or direct mount unpressurized cargo. The HTV-X Unpressurized Cargo Support System (UPCSS) accommodates up to four unpressurized cargo items ranging in size and mass, depending on the mission-specific manifest. The unpressurized cargo environments can be found in the HTV-X Unpressurized Cargo Standard IRD.



Cygnus NG (Northrup Grumman)

The **Northrup Grumman (NG) Cygnus Spacecraft Pressurized Cargo Module (PCM)** has the capability to dispose of up to 1200kg of FRAM unpressurized cargo. The Cygnus PCM accommodates up to two Passive Flight Releasable Attachment Mechanism (PFRAM) worksites located on the exterior of the PCM. The unpressurized cargo environments can be found in the Cygnus Vehicle Unpressurized Cargo Interface Control Document (Disposal).

Note: Currently, only the SpaceX vehicle is capable of transporting external FRAM or CEPA payloads to ISS.

Allowable Up-Mass and Volume Capacity

Attach Payload Location	Allowable Payload Weight (including Flight Support Equipment)	Accommodation Weight (including adapter plate)	Total Weight	Payload Volume (W x H x L)
ELC (ExPA)	490 lb.	250 lb.	740 lb.	34” x 49” x 46”
	(222 kg)	(114 kg)	(336 kg)	(863mm x 1244mm x 1168mm)
Columbus (CEPA)	490 lb.	250 lb.	740 lb.	34” x 49” x 46”
	(222 kg)	(114 kg)	(336 kg)	(863mm x 1244mm x 1168mm)
JEM-EF	979 lb.	121 lb.	1100 lb.	31.5” x 39.4” x 72.8”
	(445 kg)	(55 kg)	(500 kg)	(800mm x 1000mm x 1850mm)

Funding, Developing, and Launching Research to ISS

Every experiment on the space station needs to be sponsored and funded to be developed, integrated, flown, and operated onboard. Several sources of funding are available to scientists for research, payload development, payload processing at NASA facilities, on-orbit operation, and more.

In general, NASA funding for space station use is obtained through NASA Research Announcements (NRAs). Funding from other government agencies, private, and non-profit entities to use the space station is obtained through research opportunities released by ISS U.S. National Laboratory, otherwise known as the Center for the Advancement of Science in Space (CASIS). Space Station International Partner funding can be obtained through their respective agencies.

ISS U.S. National Laboratory

In 2011, NASA finalized a cooperative agreement with CASIS to manage the International Space Station U.S. National Laboratory (ISS National Lab). The independent, nonprofit research management organization ensures the station's unique capabilities are available to the broadest possible cross section of U.S. scientific, technological and industrial communities.

The ISS National Lab develops and manages a varied research and development portfolio based on U.S. national needs for basic and applied research. It establishes a marketplace to facilitate matching research pathways with qualified funding sources and stimulates interest in using the national lab for research and technology demonstrations and as a platform for science, technology, engineering and mathematics education. The goal is to support, promote and accelerate innovations and new discoveries in science, engineering and technology that will improve life on Earth.

More information on ISS National Lab, including proposal announcements, is available at www.issnationallab.org.

Other Government Agencies

Potential funding for research on the ISS is also available via governmental partnerships with ISS U.S. National Laboratory and includes (but is not limited to) such government agencies as:

- Department of Energy (DOE)
- Department of Defense (DOD)
- National Science Foundation (NSF)
- National Institutes of Health (NIH)
- U.S. Department of Agriculture (USDA) International Funding Sources

International Funding Sources

Unique and integral to the ISS are the partnerships established between the United States, Russia, Japan, Canada and Europe. All partners share in the greatest international project of all time, providing various research and experiment opportunities for all. These organizations – Japan Aerospace Exploration Agency (JAXA), Canadian Space Agency (CSA), ESA (European Space Agency), Russian space agency Roscosmos, Centre National d'Etudes Spatiales (CNES), and the German Aerospace Center (DLR) – provide potential funding opportunities for international scientists from many diverse disciplines.

ISS Commercial

An additional method to conduct research and other activity on the ISS is through commercial activity. NASA has opened the International Space Station (ISS) for business to enable commercial and marketing opportunities on the microgravity laboratory. Since then, there has been a growing demand for commercial and marketing activities from both traditional aerospace companies and from novel industries, demonstrating the benefits of the space station to help catalyze and expand space exploration markets and the low-Earth orbit economy.

NASA's Commercial LEO Development Program supports the development of commercially-owned and operated LEO destinations from which NASA, along with other customers, can purchase services and stimulate the growth of commercial activities in LEO. As commercial LEO destinations (CLDs) become available, NASA intends to implement an orderly transition from current International Space Station (ISS) operations to these new CLDs. Transition of LEO operations to the private sector will yield efficiencies in the long term, enabling NASA to shift resources towards other objectives. With the introduction of CLDs, NASA expects to realize efficiencies from the use of smaller, more modern and efficient platforms and a more commercial approach to meeting the Agency's needs in LEO. In the longer term, the gradual emergence of additional customers for commercial LEO destinations will offer the opportunity for additional savings.

The extension of ISS operations to 2030 will continue to return benefits to the United States and to humanity as a whole while preparing for a successful transition of capabilities to one or more commercially-owned and -operated LEO destinations (CLDs). NASA has entered into a contract for commercial modules to be attached to a space station docking port and awarded space act agreements for design of three free-flying commercial space stations. U.S. industry is developing these commercial destinations to begin operations in the late 2020s for both government and private-sector customers, concurrent with space station operations, to ensure these new capabilities can meet the needs of the United States and its partners.

Working with NASA

Once a payload has been selected for development, engineering and operations staff in the ISS Program Office are available to work with payload teams through the design, test, certification, build, and launch phases prior to beginning mission operations on ISS. More detailed information on this process, and information on current and planned launch vehicles, is available at https://www.nasa.gov/mission_pages/station/research/research_information.html.

Potential proposers to any NASA program announcement should contact the relevant Program Scientist to discuss the appropriateness of their concepts for the specific solicitation and to determine who to contact within the ISS Program Office for discussing expected development costs for their proposal budgets.

Acronyms

BAD	Broadcast Ancillary Data
C&DH	Command and Data Handling
CEPA	Columbus External Payload Adapter
ECLSS	Environmental Control & Life Support Systems
EEU	Experimental Exchange Unit
ELC	EXPRESS Logistics Carrier
ESA	European Space Agency
EVA	Extravehicular Activity (spacewalk)
EXPRESS	Expedite the Processing of Experiments for Space Station Rack
FRAM	Flight Releasable Attachment Mechanism
ICD	Interface Control Document
ICU	Integrated Communications Unit
ISS	International Space Station
JEM	Japanese Experiment Module
JEM-EF	JEM Exposed Facility
LEO	Low Earth Orbit
LOS	Loss of Signal
MCC	Mission Control Center
MISSE	Materials on International Space Station Experiment
MSS	Mobile Servicing System
NASA	National Aeronautics and Space Administration
PIM	Payload Integration Manager
PL MDM	Payload Multiplexer De-Multiplexer
PRCU	Payload Rack Checkout Unit
RIM	Research Integration Manager
RMS	Robotic Manipulator System
SE	Safety Engineer
TDRSS	Tracking and Data Relay Satellite System
TEA	Attitude Torque Equilibrium Attitude
TREK	Telescience Resource Kit
TRL	Technology Readiness Levels
WORF	Window Observational Research Facility

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For more information...

Space Station Science
https://www.nasa.gov/iss-science

Station Research Facilities/Capabilities
https://www.nasa.gov/stationfacilities

Station Research Opportunities
https://www.nasa.gov/stationopportunities

Station Research Experiments/Results
https://go.nasa.gov/researchexplorer

Station Research Benefits for Humanity
https://www.nasa.gov/stationbenefits

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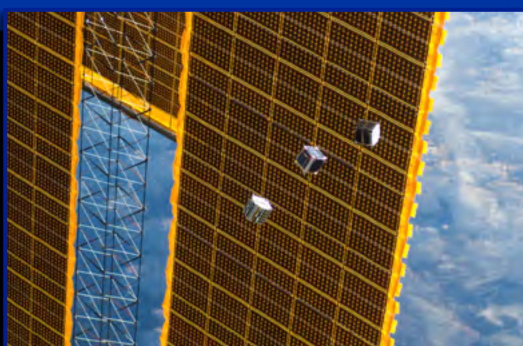

National Aeronautics and Space Administration

Johnson Space Center
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