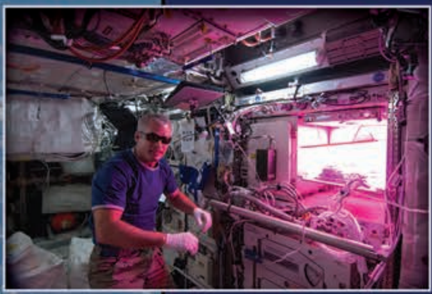
National Aeronautics and Space Administration

REFERENCE GUIDE TO THE INTERNATIONAL SPACE STATION



UTILIZATION EDITION

SEPTEMBER 2015

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INTERNATIONAL SPACE STATION

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FRONT COVER: *Images from top to bottom: 1. NASA astronaut Steve Swanson is photographed near the Veggie facility in ExPRESS (Expedite the Processing of Experiments to Space Station) Rack 3 (ER3) during Veg-01 experiment initialization. 2. Japan Aerospace Exploration Agency astronaut Aki Hoshide snaps a selfie, while in the midst of completing repairs on the ISS. In his visor you can see the robotic arm and the reflection of earth, while the sun shines behind him. 3. View of the Midwestern United States city lights at night with Aurora Borealis.*

MESSAGE FROM THE PROGRAM MANAGER BACKGROUND:
The night lights of cities in North and South America glow in this image captured by the Suomi NPP satellite and mapped over existing imagery of Earth. The Suomi NPP satellite has a Visible Infrared Imaging Radiometer Suite which allows it to detect light in a range of wavelengths from green to near-infrared and uses filtering techniques to observe dim signals such as city lights, gas flares, auroras, wildfires and reflected moonlight. This image provides new meaning to the Earth being a spaceship traveling through the darkness and overwhelming expanse of space.

Reference guide to the International Space Station. – Utlization Edition.
NP-2015-05-022-JSC

A World-Class Laboratory in Space

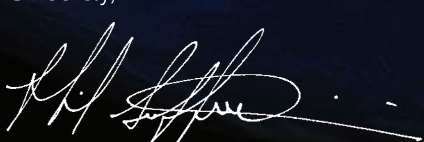
I am pleased to provide this 2015 International Space Station (ISS) Reference Guide, Utilization Edition. The unique environment of space and the full capabilities of the ISS are available for innovative commercial use, including academic and government research. In this edition, we provide an overview of the ISS, describe its research facilities and accommodations, and provide key information to conduct your experiments on this unique orbiting laboratory.

As of this writing, NASA and the space agencies of Russia, Japan, Europe and Canada have hosted investigators from 83 nations to conduct over 1700 investigations in the long-term micro-gravity environment on-board the ISS. Many investigators have published their findings and others are incorporating findings into follow-on investigations on the ground and onboard. Their research in the areas of earth and space science, biology, human physiology, physical sciences, and technology demonstration will bring yet to be discovered benefits to humankind and prepare us for our journey beyond low Earth orbit.

While ISS has proven its value as a platform for a broad waterfront of research disciplines and technology development for exploration, NASA and the Center for the Advancement of Science in Space (CASIS), are providing an ideal opportunity to test new business relationships. One that allows a shift from a paradigm of government-funded, contractor-provided goods and services to a commercially provided, government-as-a-customer approach. From commercial firms spending some of their research and development funds to conduct applied research on the ISS, to commercial service providers selling unique services to users of the orbiting lab, the beginnings of a new economy in LEO are starting to emerge.

Please enjoy this latest iteration of the ISS Reference Guide and its focus on conducting pioneering science in micro-gravity. Herein we cover current capabilities, but the ISS is an extremely flexible platform. I invite you to use the additional resources listed in the back of this guide to learn more and I hope to work with you to conduct your experiment onboard the ISS soon. Please let us know if you have other needs to support your use of this amazing platform.

Sincerely,



MICHAEL T. SUFFREDINI
ISS Program Manager

Contents

Research/
Research Accommodations

The International Space Station (ISS) is a unique scientific platform that enables researchers from all over the world to put their talents to work on innovative experiments that could not be done anywhere else. Although each space station partner has distinct agency goals for station research, each partner shares a unified goal to extend the resulting knowledge for the betterment of humanity. Through advancing the state of scientific knowledge of our planet, looking after our health, developing advanced technologies and providing a space platform that inspires and educates the science and technology leaders of tomorrow, the benefits of the ISS will drive the legacy of the space station as its research strengthens economies and enhances the quality of life here on Earth for all people.

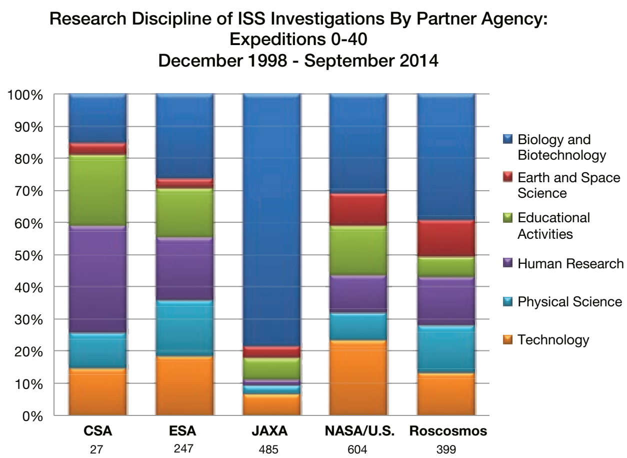
The Lab Is Open

Unique Features of the ISS Research Environment

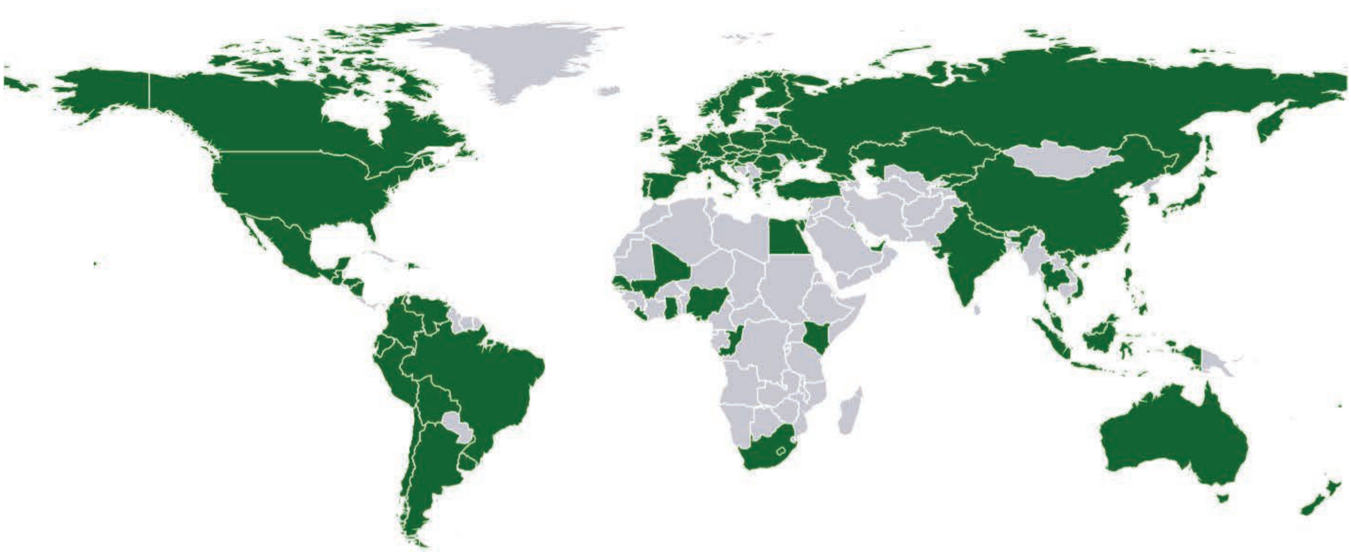
Microgravity, or weightlessness, alters many observable phenomena within the physical and life sciences. Systems and processes affected by microgravity include surface wetting and interfacial tension, multiphase flow and heat transfer, multiphase system dynamics, solidification, and fire phenomena and combustion. Microgravity induces a vast array of changes in organisms ranging from bacteria to humans, including global alterations in gene expression and 3-D aggregation of cells into tissue-like architecture.

Extreme conditions in the ISS space environment include exposure to extreme heat and cold cycling, ultra-vacuum, atomic oxygen, and high energy radiation. Testing and qualification of materials exposed to these extreme conditions have provided data to enable the manufacturing of long-life reliable components used on Earth as well as in the world's most sophisticated satellite and spacecraft components.

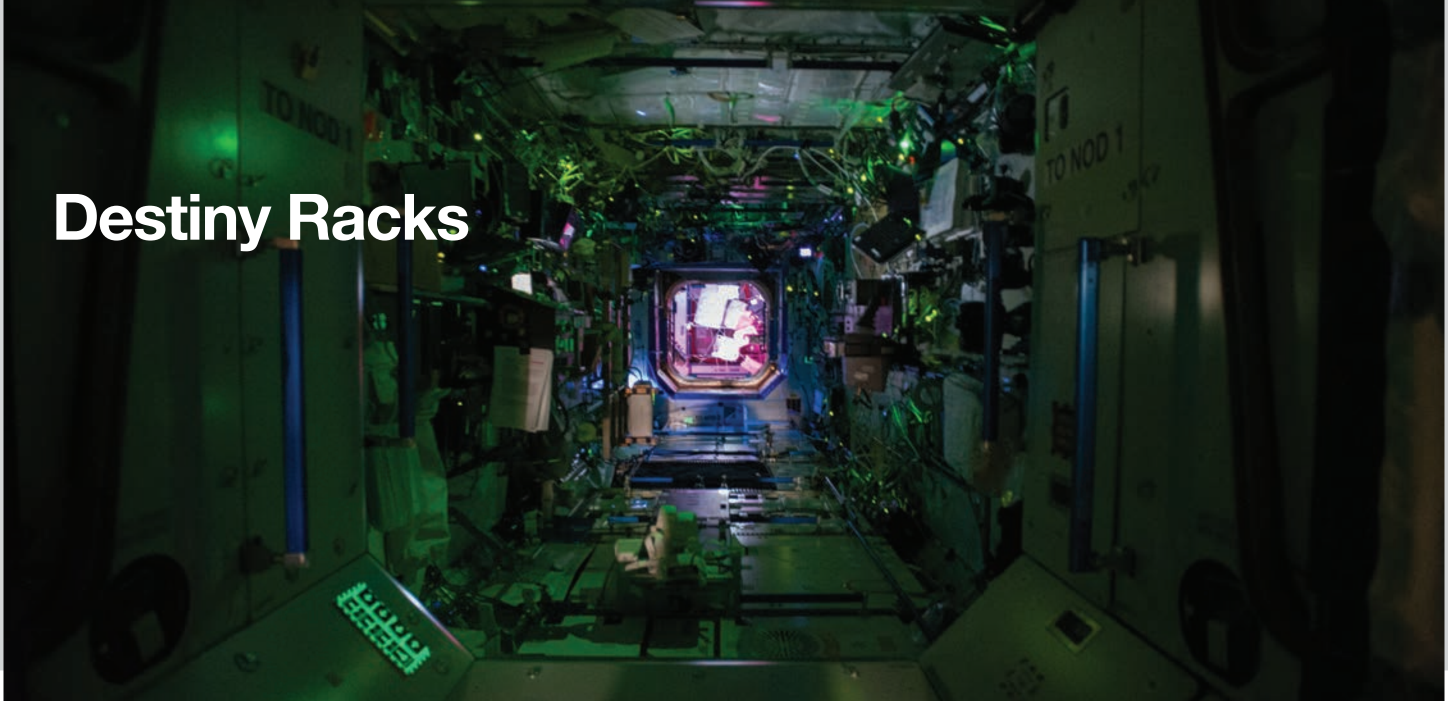
Low-Earth orbit at 51 degrees inclination and at a 90-minute orbit affords ISS a unique vantage point with an altitude of approximately 240 miles (400 kilometers) and an orbital path over 90 percent of the Earth's population. This can provide improved spatial resolution and variable lighting conditions compared to the sun-synchronous orbits of typical Earth remote-sensing satellites.



Through Expedition 40, 83 countries and areas (highlighted in green) have been involved in ISS Research and Educational activities



Destiny Racks



This view in the International Space Station is looking into the Destiny Laboratory from Node 1 (Unity) with Node 2 (Harmony) in the background.

EXPRESS Rack 1

Sub-rack-sized experiments with standard utilities such as power, data, cooling, and gases.

EXPRESS Rack 2

Sub-rack-sized experiments with standard utilities such as power, data, cooling, and gases.

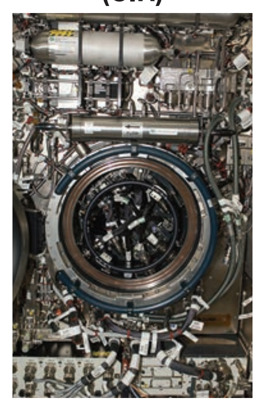
EXPRESS Rack 6

Sub-rack-sized experiments with standard utilities such as power, data, cooling, and gases.

EXPRESS Rack 7

Sub-rack-sized experiments with standard utilities such as power, data, cooling, and gases.

Combustion Integrated Rack (CIR)



Used to perform sustained, systematic combustion experiments in microgravity.

Fluids Integrated Rack (FIR)

A complementary fluid physics research facility designed to accommodate a wide variety of microgravity experiments.

Materials Science Research Rack-1 (MSRR-1)

Accommodates studies of many different types of materials.

Microgravity Science Glovebox (MSG)

A dedicated science facility that provides a sealed environment to perform many different types of small “glovebox” sized experiments.

Window Observational Research Facility (WORF)

Provides a facility for Earth science research using the Destiny science window on the ISS.

Minus Eighty-Degree Laboratory Freezer for ISS (MELFI-3)

A refrigerator/freezer for biological and life science samples.

Kibo Racks

NASA astronaut Reid Wiseman conducts a session with the Binary Colloidal Alloy Test (BCAT) experiment in the Kibo laboratory of the International Space Station.

Minus Eighty-Degree Laboratory Freezer for ISS (MELFI-1)

A refrigerator/freezer for biological and life science samples.

Minus Eighty-Degree Laboratory Freezer for ISS (MELFI-2)

A refrigerator/freezer for biological and life science samples.

Multipurpose Small Payload Rack 1 (MSPR-1)

Multipurpose rack accommodating small experiments from various science disciplines.

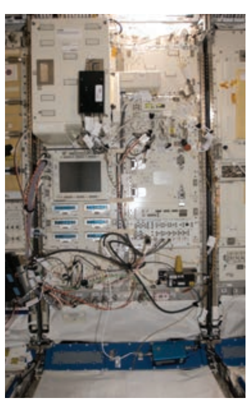
EXPRESS Rack 4

Sub-rack-sized experiments with standard utilities such as power, data, cooling, and gases.

EXPRESS Rack 5

Sub-rack-sized experiments with standard utilities such as power, data, cooling, and gases.

Ryutai Experiment Rack



A multipurpose payload rack system that supports various fluid physics experiments.

Saibo Experiment Rack

A multipurpose payload rack system that sustains life science experiment units inside and supplies resources to them.

KOBAIRO

Science experiment rack accommodating a gradient heating furnace for material studies.

Columbus Racks

NASA astronaut Dan Burbank uses Neurospat hardware to perform a science session with the PASSAGES experiment in the Columbus laboratory.

EXPRESS Rack 3

Sub-rack-sized experiments with standard utilities such as power, data, cooling, and gases.

Multipurpose Small Payload Rack 1 (MSPR-1)

Multipurpose rack accommodating small experiments from various science disciplines.

Muscle Atrophy Research and Exercise System (MARES)

Used for research on musculoskeletal, biomechanical, and neuromuscular human physiology.

Human Research Facility (HRF-1)

Enable researchers to study and evaluate the physiological, behavioral, and chemical changes induced by long-duration space flight.

Human Research Facility (HRF-2)

Enable researchers to study and evaluate the physiological, behavioral, and chemical changes induced by long-duration space flight.

Biological Experiment Laboratory (BioLab)

Used to perform space biology experiments on microorganisms, cells, tissue cultures, small plants, and small invertebrates.

European Drawer Rack (EDR)

Provides sub-rack-sized experiments with standard utilities such as power, data, and cooling.

European Physiology Module (EPM)

Investigates the effects of short- and long-duration space flight on the human body.

Fluid Science Laboratory (FSL)

A multi-user facility for conducting fluid physics research in micro-gravity conditions.

KOBAIRO

Science experiment rack accommodating a gradient heating furnace for material studies.

Internal Research Accommodations

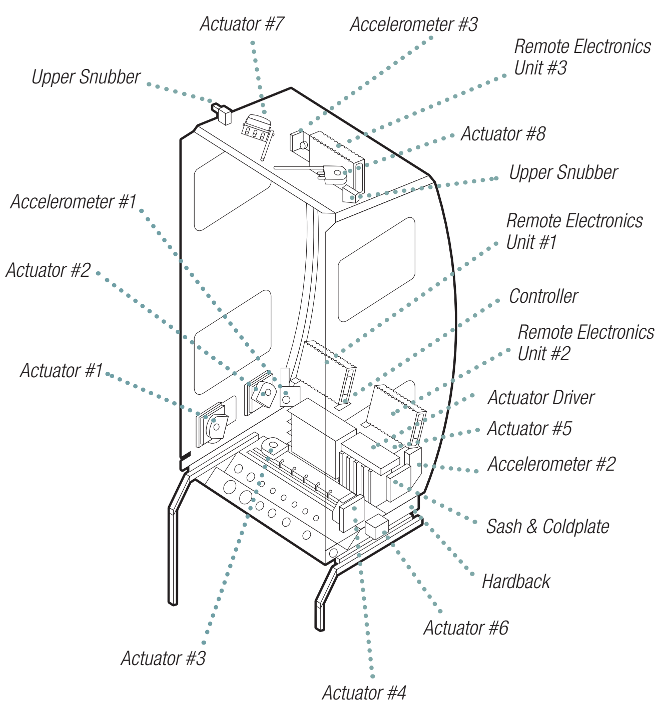
Several research facilities are in place aboard the ISS to support microgravity science investigations, including those in biology, biotechnology, human physiology, material science, physical sciences, and technology development.

Standard Payload Racks

Research payload within the U.S., European, and Japanese laboratories typically are housed in a standard rack, such as the International Standard Payload Rack (ISPR). Smaller payloads may fit in ISS lockers carried in a rack framework.

Active Rack Isolation System (ARIS)

The ARIS is designed to isolate payload racks from vibration. The ARIS is an active electromechanical damping system attached to a standard rack that senses the vibratory environment with accelerometers and then damps it by introducing a compensating force.

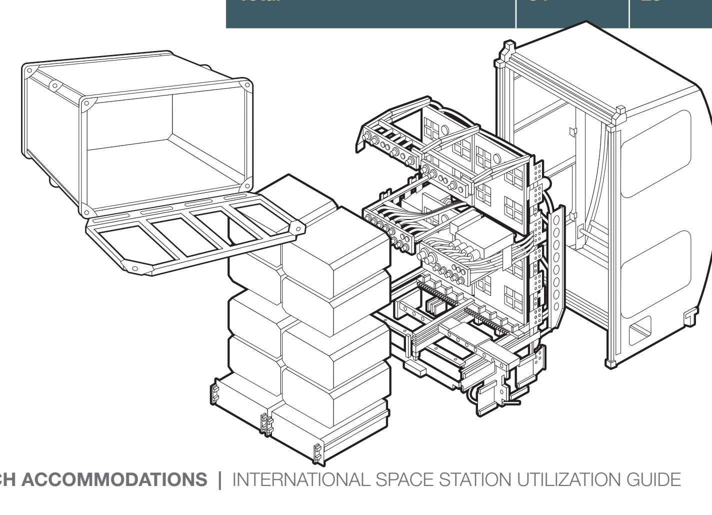


Power	
3, 6, or 12 kW, 114.5 to 126 voltage, direct current (VDC)	
Data	
Low rate	MIL-STD-1553 bus 1 Mbps
High rate	100 Mbps
Ethernet	10 Mbps
Video	NTSC
Gases	
Nitrogen flow	0.1 kg/min minimum 517 to 827 kPa, nominal 1,379 kPa, maximum
Argon, carbon dioxide, helium	517 to 768 kPa, nominal 1,379 kPa, maximum
Cooling Loops	
Moderate temperature	16.1 to 18.3 °C
Flow rate	0 to 45.36 kg/h
Low temperature	3.3 to 5.6 °C
Flow rate	233 kg/h
Vacuum	
Venting	10^{-3} torr in less than 2 h for single payload of 100 L
Vacuum resource	10^{-3} torr

Research Rack Locations

International Pressurized Sites	Total by Module	U.S. Shared
U.S. Destiny Laboratory	13	13
Japanese Kibo Laboratory	11	5
European Columbus Laboratory	10	5
Total	**34**	**23**

NASA astronaut Sunita Williams works in MELFI-2 rack in the U.S. Laboratory/Destiny.

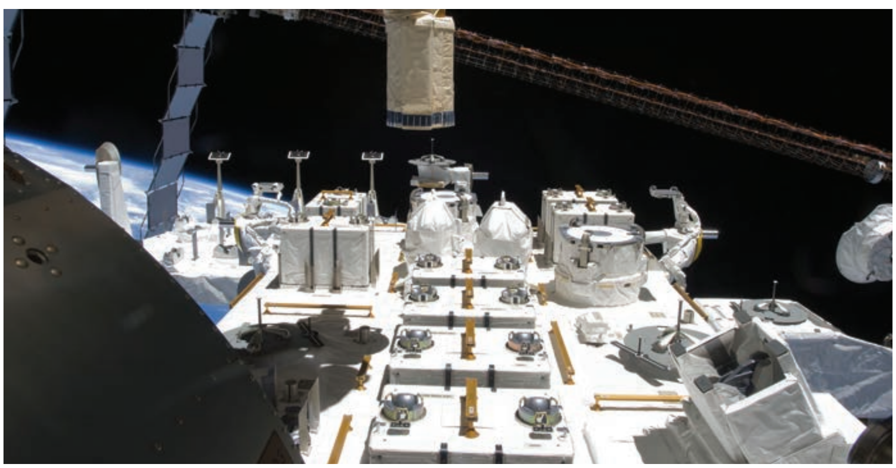


External Research Accommodations

External Earth and Space Science hardware platforms are located at various places along the outside of the ISS. Locations include the Columbus External Payload Facility (CEPF), Russian Service Module, Japanese Experiment Module Exposed Facility (JEM-EF), four EXPRESS Logistics Carriers (ELC), and the Alpha Magnetic Spectrometer (AMS). External facility investigations include those related to astronomy; Earth observation; and exposure to vacuum, radiation, extreme temperature, and orbital debris.

External Payload Accommodations

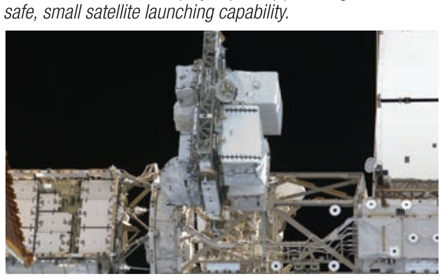
External payloads may be accommodated at several locations on the U.S. S3 and P3 Truss segments. External payloads are accommodated on an Expedite the Processing of Experiments to the Space Station racks (EXPRESS) Logistics Carrier (ELC). Mounting spaces are provided, and interfaces for power and data are standardized to provide quick and straightforward payload integration. Payloads can be mounted using the Special Purpose Dexterous Manipulator (SPDM), Dextre, on the ISS's robotic arm.



Japanese Experiment Module Exposed Facility (JEM-EF).

The European Columbus Research Laboratory has four exterior mounting platforms that can accommodate external payloads.

Small Satellite Orbital Deployer (SSOD) providing a novel, safe, small satellite launching capability.



Exterior nadir view of the ExPRESS Logistics Carrier 1 (ELC1) mounted to the P3 truss segment.

Express Logistics Carrier (ELC) Resources	
Mass capacity	227 kg (8 sites across 4 ELCs; not including adaptor plate)
Volume	1.2 m³
Power	750 W, 113 to 126 VDC 500 W at 28 VDC per adapter
Thermal	Active heating, passive cooling
Low-rate data	1 Mbps (MIL-STD-1553)
Medium-rate data	6 Mbps (shared)

Kibo Exposed Facility Resources	
Mass capacity	– 500 kg Standard Site (10 Standard Sites, mass includes PIU adaptor) – 2500 kg Heavy Site (3 Heavy Sites, mass includes PIU adaptor)
Volume	1.5 m³
Power	3 kW max, 113-126 VDC
Thermal	3–6 kW cooling
Low-rate data	1 Mbps (MIL-STD-1553)
High-rate data	43 Mbps (shared) Ethernet: 100 Base-TX

Columbus External Payload Facility (CEPF) Resources	
Mass capacity	230 kg per site (4 sites; uses Columbus External Payload Adapter (CEPA)
Volume	1.2 m³
Power	1250 W, 120 VDC
Thermal	Passive
Low-rate data	1 Mbps (MIL-STD-1553)
Medium-rate data	2 Mbps (shared) Ethernet: 100 Base-TX

External Research Locations

External Unpressurized Attachment Sites	Stationwide	U.S. Shared
U.S. Truss	8	8
Japanese Exposed Facility	10	5
European Columbus Research Laboratory	4	2
Total	22	15

Biological Sciences and Biotechnology

ESA astronaut Alexander Gerst working on the T-Cell Activation investigation.

View of Russian cosmonaut Elena Serova as she performs the RJR Augmented Microbial Sampling investigation by taking air samples with Microbial Air Sampler.

NASA astronaut Karen Nyberg harvests plants from JAXA's Resist Tubule investigation.

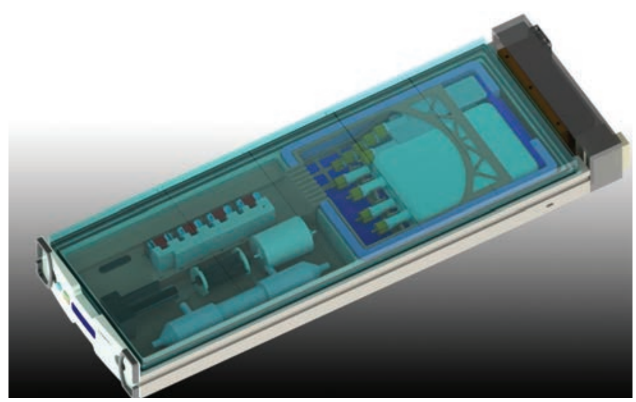
The ISS has scientific capabilities to provide a unique laboratory to investigate biological or life sciences without the constraint of gravity. Biological researchers are investigating a multitude of questions that include the role of gravity and genomic diversity in biological processes. They are also contributing to finding solutions for biomedical problems that occur both on Earth and in space, in addition to the biological responses to multiple stressors.

Cells, microbes, animals and plants have evolved and developed in gravity, and the role of this environment on the regulation of biological processes is beginning to be understood. Genetic diversity in some systems is obscured in the Earth environment; use of a microgravity environment is providing unique insights into such regulation. Previous microgravity studies observed increased virulence in microbes, pluripotency of stem cells, and tissue morphogenesis patterns.

Results obtained from ISS research have implications for understanding basic biological processes, understanding stress response, developing drugs and therapeutics that can combat diseases, improving food supplies on Earth, and enhancing life-support capabilities for the exploration of space. In addition, better understanding of some of these biological processes (such as microbial virulence and the behavior of planktonic vs. biofilm forms of bacteria) could also have implications for astronaut health and also for improving life here on Earth.

Cellular and Molecular Biology

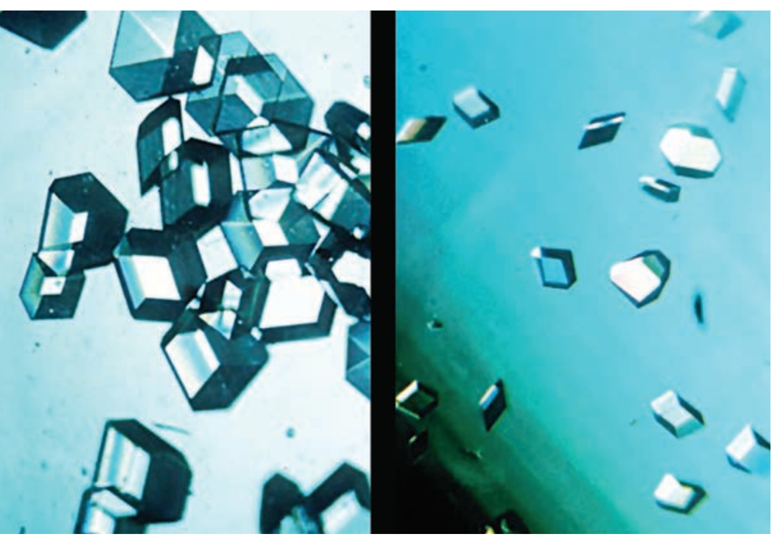
Cellular Biology includes cell culture, tissue culture and related microbial (single-cell organism) experiments. These cell-based studies in microgravity support many areas of basic and applied research for space exploration and Earth applications. The environment of space offers a unique opportunity for novel discoveries of cellular and tissue adaptation. These novel discoveries have applications in understanding changes to human health during long-duration spaceflight and to Earth-based medicine in such areas of biomedical research as tissue engineering, host-pathogen interactions, vaccine development and drug discovery. Using gravity as a variable enables two broad classes of space cell biology research: (a) understanding fundamental mechanisms of life's responses to changes in gravity and (b) using gravity as a tool to advance biological applications in the field of tissue engineering.



Top view of enclosed Bioculture System cassette. Image courtesy of Tissue Genesis, Inc.

Hand-Held High Density Protein Crystal Growth (HDPCG).

In the area of molecular biology, protein crystallization is at the forefront of this discipline. Proteins are biological macromolecules that function in an aqueous environment. Biotechnology and pharmaceutical researchers carry out the process of protein crystallization in order to grow large, well-ordered crystals for use in X-ray and neutron diffraction studies. However, on Earth, the protein crystallization process is hindered by forces of sedimentation and convection since the molecules in the crystal solution are not of uniform size and weight. This leads to many crystals of irregular shape and small size that are unusable for diffraction. Diffraction is a complex process and the quality of data obtained about the three-dimensional structure of a protein is directly dependent on the degree of perfection of the crystals. Thus, the structures of many important proteins remain a mystery simply because researchers are unable to obtain crystals of high quality or large size. Consequently, the growth of high quality macromolecular crystals for diffraction analysis has been of primary importance for protein engineers, biochemists, and pharmacologists.



Hand-Held High Density Protein Crystal Growth (HDPCG).

Fortunately, the microgravity environment aboard the ISS is relatively free from the effects of sedimentation and convection and provides an exceptional environment for crystal growth. Crystals grown in microgravity could help scientists gain detailed knowledge of the atomic, three-dimensional structure of many important protein molecules used in pharmaceutical research for cancer treatments, stroke prevention and other diseases. The knowledge gained could be instrumental in the design and testing of new drugs.

Microbial Research

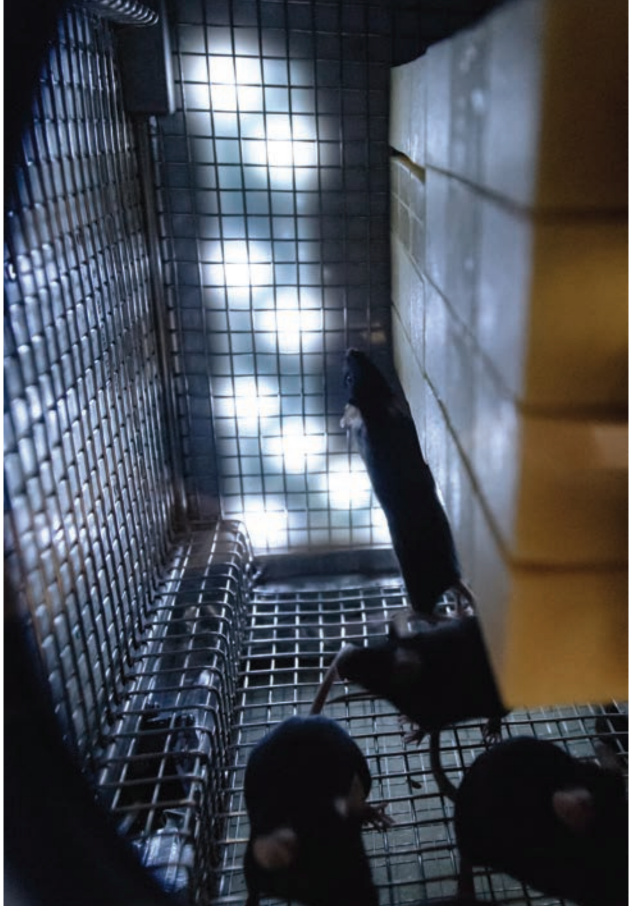
NASA astronaut Reid Wiseman activates the BRIC-19 investigation.

A human is both an individual organism and an entire ecosystem, including microorganisms in, on, and around them in which the human cells are greatly outnumbered by the microbial cells. The microbial inhabitants in and on the person outnumber the human cells 10 to 1. For the most part, these microorganisms are beneficial to their human host or otherwise innocuous. Given the right opportunity, either a shift in the environment of the host or the invasion to a new location within the host, can cause the microorganisms to become pathogenic.

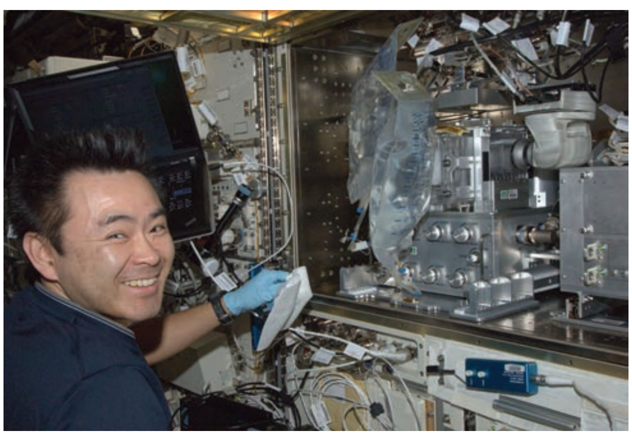
Significant strides have been made to define and mitigate the source of microbial contamination aboard spacecraft and to document the responses of numerous microorganisms to the spaceflight environment. Both experience and research data has helped in the identification of critical gaps in scientist's understanding of how this environment impacts microbial ecology, the microbial genotypic and phenotypic characteristics, and their interactions with plant and animal hosts. As we look toward human interplanetary exploration, the importance of this knowledge has been recognized. With the increases in both the occupancy and duration of humans aboard the ISS, these knowledge gaps are becoming better defined. With the laboratory platform aboard ISS, many of these gaps for future spaceflight can be understood.

Animal Biology

The International Space Station provides a unique environment in which to study the effects of microgravity and the space environment on various organisms. Rodents (rats and mice) are the animal models most commonly used to study fundamental biological processes in space: predominately rats, followed by mice. Given that human astronauts and



Interior view of the rodents found within the rodent habitat.



JAXA astronaut Aki Hoshide works on the Multipurpose Small Payload Rack (MSPR) in preparation for the arrival of the JAXA Medaka Osteoclast experiment.

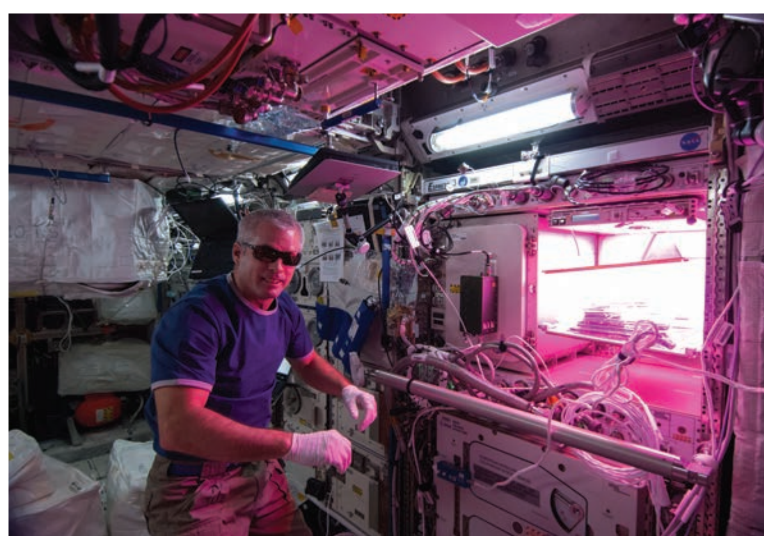
cosmonauts routinely spend 180 days or longer on the ISS, that amount of time represents a significant portion of the lifespan of a rodent. Studies with rodents in space have been useful and important for extrapolating the implications for humans living in space and more work remains to be done (National Research Council [U.S.], 2011).

One example is the leveraging of current technology such as using genetically engineered mice in flight experiments to investigate the molecular mechanisms of bone loss that occurs during exposure to microgravity for possible pharmacological intervention. NASA is particularly interested in studies that enable a better understanding of how mechanisms governing homeostasis at the genetic, molecular and cellular levels are integrated to regulate adaptation to spaceflight at the physiological system or whole-animal level.

Plant Biology

The progress in plant space biology over the past quarter century has greatly increased our understanding of how plants: respond to gravity; informed the design of advanced plant growth facilities; achieved the completed life cycle; and demonstrated that physiological processes necessary for biological life support are sustainable. In the process, the horticulture of plants in the unique environment of microgravity was being developed, and plant/microbe interactions were explored. The advances made during the decades of spaceflight experimentation have also identified critical gaps in our understanding of the role of gravity and the spaceflight environment on plant biology at the cellular, tissue, whole plant, and community levels.

In this context, the International Space Station is a unique platform where reduced gravity can be used to probe and dissect biological mechanisms in plants for understanding how terrestrial biology responds to gravity. This knowledge is important for supporting safe and long-term human habitation in space using bio-regenerative life support, utilizing plants and microbial communities, and for reducing exploration risks to crews by designing countermeasures to problems associated with living in space. In addition, by using the facilities with centrifuges, scientists can investigate how plants respond to the reduced gravity environments on the moon and Mars.



NASA astronaut Steve Swanson is photographed near the Veggie facility in ExPRESS (Expedite the Processing of Experiments to Space Station).

Human Research

NASA astronaut Catherine Coleman prepares to insert samples into the Minus Eighty Degree Laboratory Freezer for ISS (MELFI).

NASA astronaut Terry Virts must maintain a well balanced diet while in microgravity to help avoid additional bone and muscle loss.

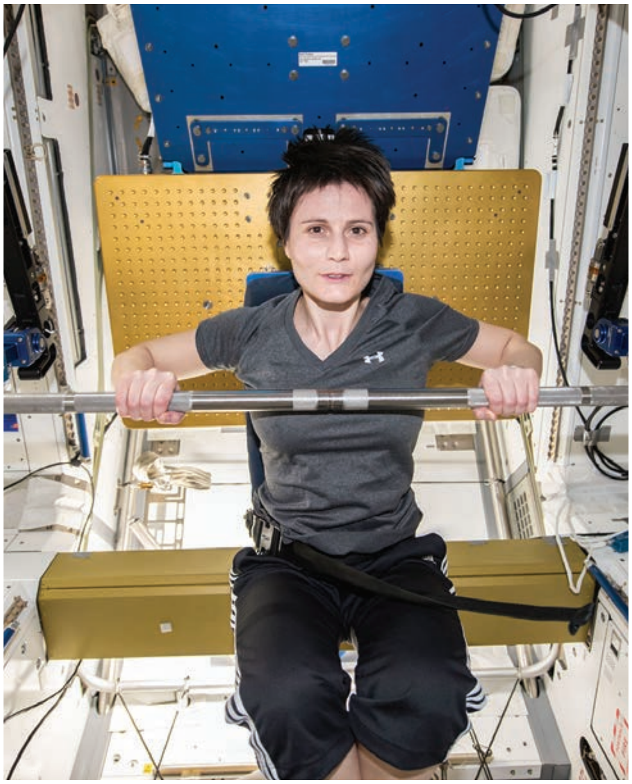
NASA astronaut Sunita Williams as she underwent a blood draw to support Human Research.

NASA's history has proven that humans are able to live safely and work in space. The ISS serves as a platform to extend and sustain human activities in preparation for long-duration, exploration-class missions. It provides opportunities to address critical medical questions about astronaut health through multidisciplinary research operations to advance our understanding and capabilities for space exploration.

The multi-disciplinary biomedical research currently underway on the ISS include studies addressing behavioral health and performance, bone and muscle physiology, exercise countermeasures, cardiovascular physiology, nutrition, and immunology. These life sciences research studies aim to provide a thorough understanding of the many physiologic changes that occur in a microgravity environment. Among the many physiological changes that occur in the human body include susceptibility to fainting after landing, vision changes potentially because of the harmful effects of microgravity on the eye and optic nerve, changes in blood volume, reduction in heart size and capacity, alterations in posture and locomotion, decreases in aerobic capacity and muscle tone, difficulty sleeping, increased risk for renal stone formation, and weakened bones.

The research focuses on astronaut health and performance and the development of countermeasures that will protect crew members from the space environment during long-duration voyages, evaluate new technologies to meet the needs of future exploration missions and develop and validate operational procedures for long-duration space missions.

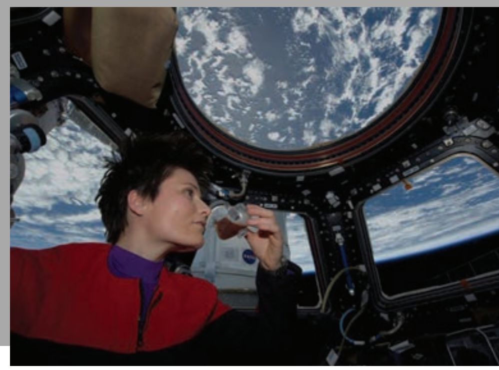
NASA astronaut Michael Hopkins performs ultrasound eye imaging while European Space Agency astronaut Luca Parmitano assists.



ESA astronaut Samantha Cristoforetti exercises on the Advanced Resistive Exercise Device (ARED).

Physical Sciences

Flame burning in microgravity.



ESA astronaut Samantha Cristoforetti using the Capillary Beverage Cup in the Cupola.

A close-up view of the Capillary Flow Experiments-2.

The ISS provides a long-duration spaceflight environment for conducting microgravity physical science research. The microgravity environment greatly reduces buoyancy driven convection, pressure head, and sedimentation in fluids. By eliminating gravity or using gravity as a factor in experimental design, the ISS allows physical scientists to better understand fluid physics; the dynamics of interfaces, such as the line of contact between a liquid and a gas; the physical behavior of systems made up wholly or partially of particles; combustion processes in the absence of buoyant convection and the properties of materials.

Fluid Physics

A fluid is any material that flows in response to an applied force; thus, both liquids and gases are fluids. Nearly all of the life support, environmental and biological, processes take place in the fluid phase. Fluid motion accounts for most transport and mixing in both natural and man-made processes as well as within all living organisms. Fluid physics is the study of the motions of liquids and gases and the associated transport of mass, momentum and energy. The need for a better understanding of fluid behavior has created a vigorous, multidisciplinary research community whose ongoing vitality is marked by the continuous emergence of new fields in both basic and applied science. In particular, the low- gravity environment offers a unique opportunity for the study of fluid physics and transport phenomena. The nearly weightless conditions allow researchers to observe and control fluid phenomena in ways that are not possible on Earth.

Experiments conducted in space have yielded rich results. Some were unexpected and most could not be observed in Earth-based labs. These results provided valuable insights into fundamental fluid behavior that apply to both terrestrial and space environments. In addition, research on fluid management and heat transfer for both propulsion and life-support systems, have contributed greatly to U.S. leadership in space exploration.

NASA astronaut Reid Wiseman conducts a session with the Binary Colloidal Alloy Test.

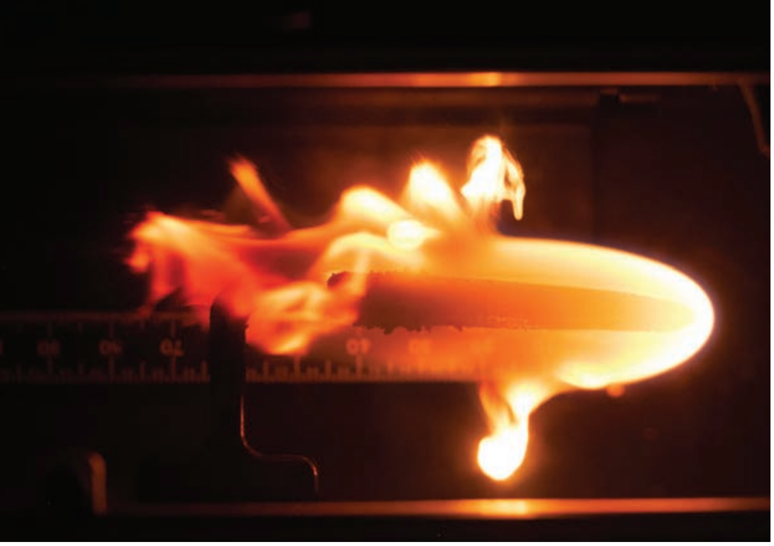


Image taken during a BASS-II (Burning and Suppression of Solids - II) experiment flame test.

Combustion

Combustion occurs when fuel and oxygen react to produce carbon dioxide, water and heat. For the foreseeable future the overwhelming majority of delivered energy in terrestrial applications will be from combustion or other chemically reacting systems. These energy uses cover the range from electric power and transportation to processes directly tied to the delivered material (e.g., glass and steel manufacture). These processes produce some of the most important environmental hazards currently facing humanity (global climate change, acid gas pollution, mercury contamination from coal, and wild-land fires).

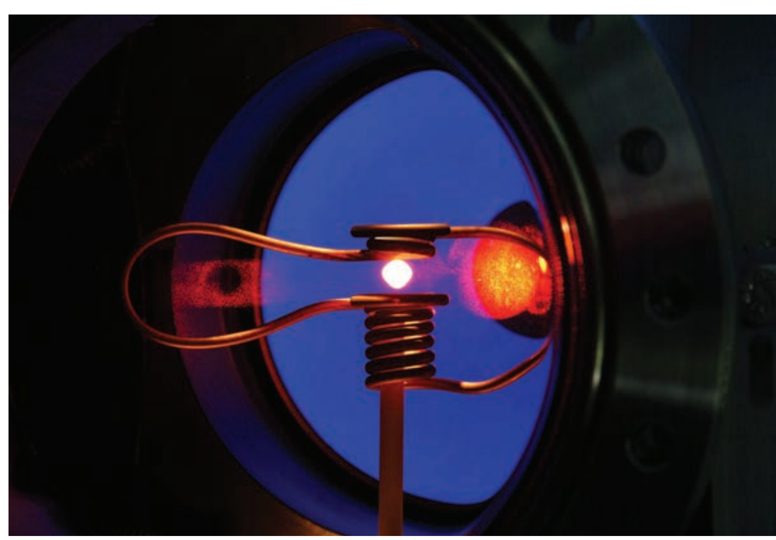
Despite being the subject of active research for over 80 years, combustion processes remain one of the most poorly controlled phenomena that have a significant impact on human health, comfort and safety. This is because the simplest combustor (e.g., kitchen stove) remains beyond our detailed numerical modeling capabilities. The combustion process typically involves a large number of chemical species (hundreds) and reactions (even thousands). It is these species and reactions that determine flammability limits (combustor operating ranges) and pollutant emissions. Much of combustion research involves developing a comprehensive and predictive quantitative understanding of this complex process.

The ISS allows for the variance or elimination of the effects of gravity. By doing this, we can extract fundamental data that is important for understanding combustion systems. This approach has been implemented to some extent in existing terrestrial reduced-gravity platforms, but the experimental time scales and sizes have been limited. Long-duration experiments using realistic sizes are essential for a comprehensive understanding of the combustion phenomena and are possible only in the microgravity environments offered by space facilities.

Materials Science

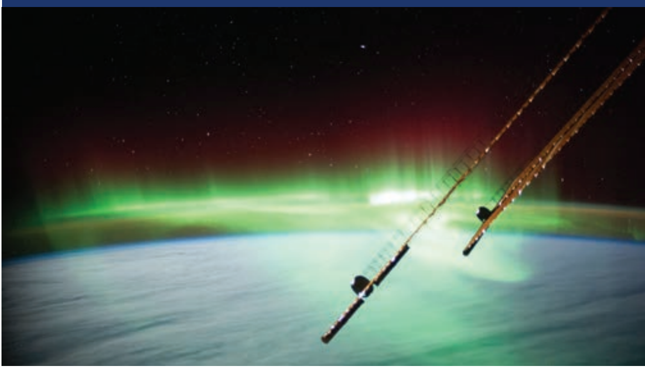
Most materials are formed from a partially or totally fluid sample and the transport of heat and mass inherently influences the formation of the material and its resultant properties. The reduction in gravity related sources of heat and mass transport may be used to determine how the material processes are affected by gravitational driven and gravitationally independent sources of heat and mass transfer.

Images of the Materials Science Research Rack (MSRR).



Interior view of the EML experiment. Image credit: European Space Agency (ESA).

Earth and Space Science



One of the more spectacular scenes of the Aurora Australis was photographed by one of the Expedition 40 crew members.

The expedition 41 crew took pictures of the Atlantic Hurricane Edouard.

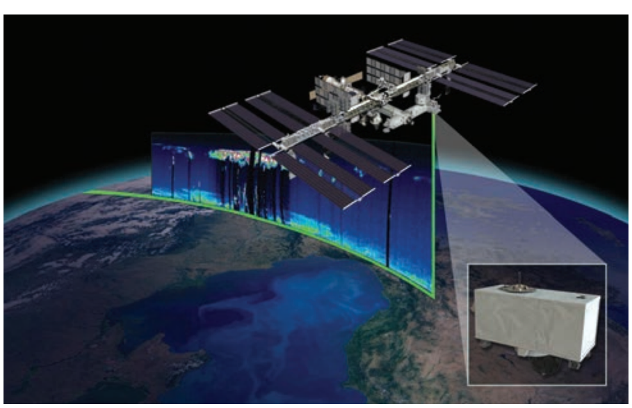
Image taken for the Hyperspectral Imager for the Coastal Ocean (HICO) investigation.

The presence of the space station in low-Earth orbit provides a vantage point for collecting Earth and space data. From an altitude of about 400 km, details in such features as Glaciers, agricultural fields, cities, and coral reefs taken from the ISS can be layered with other sources of data, such as orbiting satellites, to compile the most comprehensive information available.

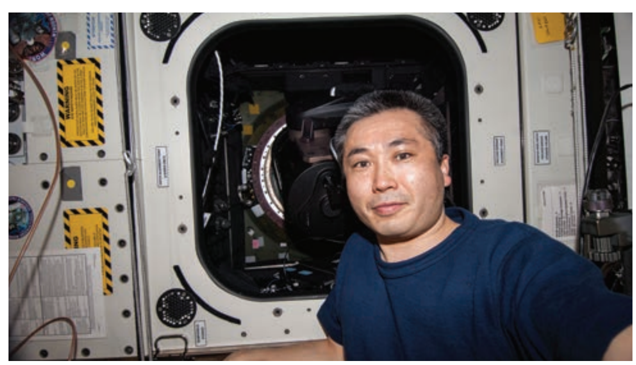
Earth Observation

While NASA and other space agencies have had remote-sensing systems orbiting Earth and collecting publically available data since the early 1970s, these sensors have been primarily carried aboard free-flying, unmanned satellites. These satellites have typically been placed into sun-synchronous polar orbits that allow for repeat imaging of the entire surface of the Earth with approximately the same sun illumination (typically local solar noon) over specific areas, with set revisit times—this allows for uniform data to be taken over long time periods and enables straightforward analysis of change over time.

The ISS is a unique remote sensing platform from several perspectives—unlike automated remote-sensing platforms—it has a human crew, a low-orbit altitude, and orbital parameters that provide variable views and lighting. The presence of a crew provides options not available to robotic sensors and platforms, such as the ability to collect unscheduled data of an unfolding event using handheld digital cameras as part of the Crew Earth Observations facility and real-time assessment of whether environmental conditions (like cloud cover) are favorable for data collection. The crew can also swap out internal sensor systems and payloads installed in the Window Observational Research Facility (WORF) on an as-needed basis.



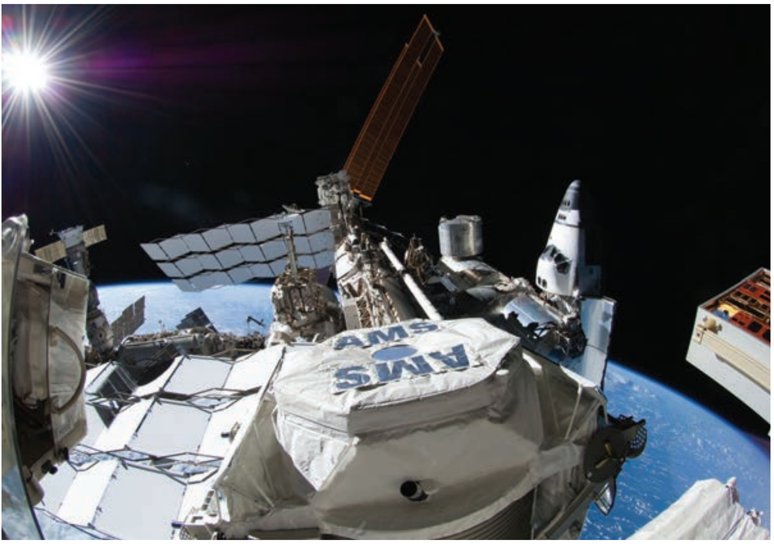
Artistic representation of the Cloud-Aerosol Transport System (CATS) that is being used to measure clouds and aerosols in the Earth's atmosphere.



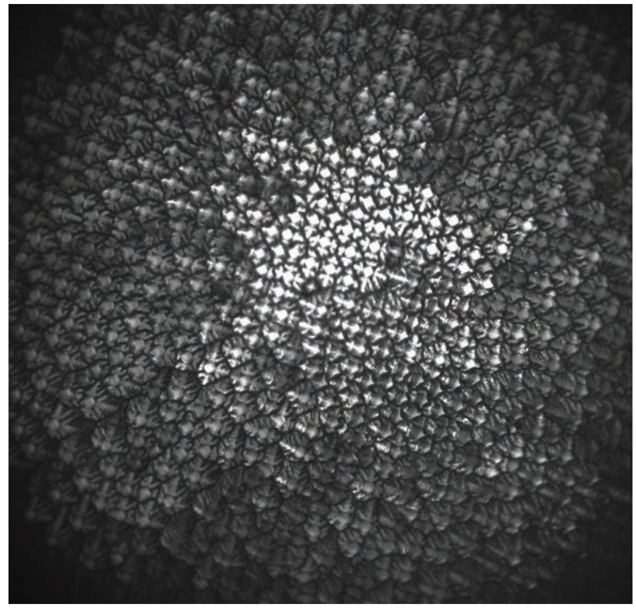
JAXA astronaut Koichi Wakata works with the Window Observational Research Facility (WORF) rack.

Artistic representation of the ISS RapidScat payload that is being used to measure wind speeds and directions over the oceans. Image credit: NASA/JPL.

Fundamental Physics



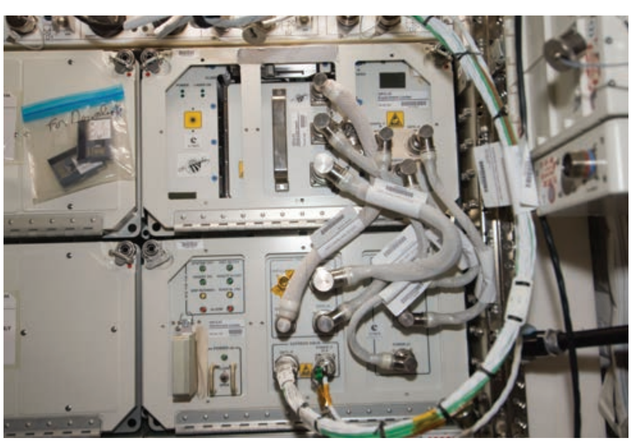
Exterior view of the International Space Station (ISS) taken during an Extravehicular Activity (EVA) with the Alpha Magnetic Spectrometer - 02 (AMS-02) visible in the foreground.


Dendritic pattern of the Succinonitrile-Camphor alloy grown in microgravity, seen from the top. Image courtesy of Nathalie Bergeon.

Studies in fundamental physics address space, time, energy, and the building blocks of matter. The primary theories of modern physics are based upon Einstein's theory of relativity and the standard model of particle physics. However, as scientists, we know that the picture painted by these theories remains incomplete. Einstein's theory of gravitation remains unproved to be consistent with the theories that define other forces of nature in all length scales. Furthermore, recent astronomical observation and cosmological models strongly suggest that dark matter and dark energy, which are entities not directly observed and not at all understood, dominate these interactions at the largest scales. All these unexplained observations and inconsistencies point to the potential for discovery of new theories. The ISS provides a modern and well-equipped orbiting laboratory for long-term micro-gravity environment research. Routine and continued access to this environment allows for fundamental physics research to be performed from a completely different vantage point.

The International Space Station provides a unique space laboratory for a set of fundamental physics experiments with regimes and precision not achievable on the ground. Some of the advantages of the space environment for experiments include:

- Long-duration exposure to the orbital free-fall environment
- Ease of measurement of changes of gravitational potential and relative motions
- Study of very small accelerations on celestial bodies
- Reduced atmospheric interference on the propagation of optical and radio signals
- Ability to track and fit to theory very long time segments of body orbital motion

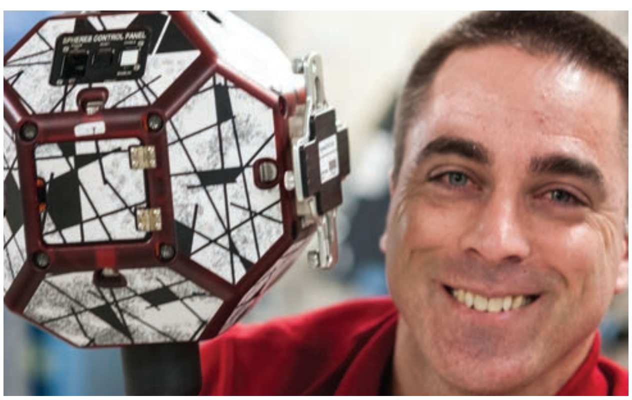

View of DEvice for the study of Critical LIquids and Crystallization (DECLIC) Experiment Locker.

Technology Demonstrations

NASA Astronaut Barry (Butch) Wilmore holds a 3-D printed ratchet wrench from the new 3-D printer.

Cyclops enables the space-based launch of a new class of satellites, which are larger than cubesats but not large enough to require their own Earth-based launch vehicles.

The ISS 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.



NASA astronaut Chris Cassidy poses for a photo while conducting a session with a pair of bowling-ball-sized free-flying satellites known as Synchronized Position Hold, Engage, Reorient, Experimental Satellites, or SPHERES.

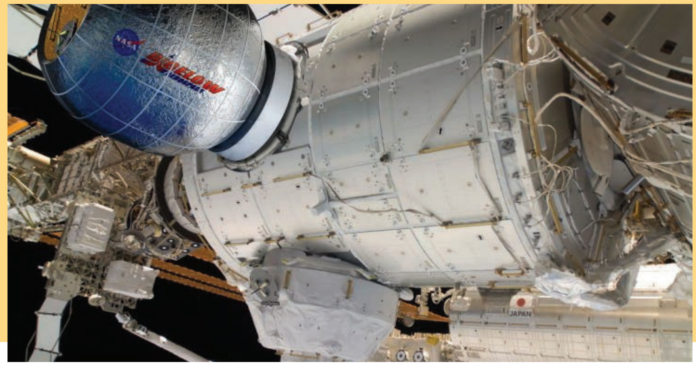
The ISS is the only long-duration platform available in the relevant space environment with an integrated space systems architecture that can be used to demonstrate advanced technologies and operations concepts. Working in close cooperation with the exploration community, the ISS Program is enabling technology and systems investigations in support of future exploration endeavors. NASA has identified 11 exploration technology areas of interest that ISS is capable of supporting.

- In-Space Propulsion
- Space Power and Energy
- Robotics, Tele-Robotics and Autonomous Systems
- Communication and Navigation
- Life Support and habitation Systems
- Exploration Destination Systems
- Science Instruments
- Entry, Descent and landing Systems
- Materials Structures and Manufacturing
- Thermal Management Systems
- Operational Processes and Procedures

NASA astronaut Steve Swanson takes a picture with Robonaut after installation of the Robonaut legs.

Commercial Development

NanoRacks CubeSat Deployer.

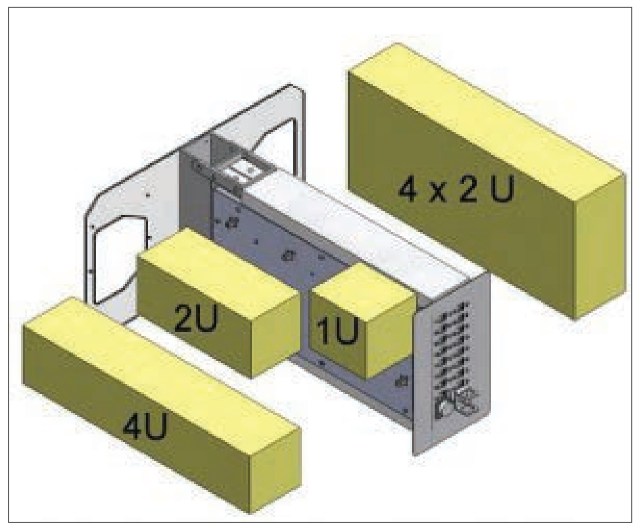


The Bigelow Expandable Activity Module. Image Courtesy of Bigelow.

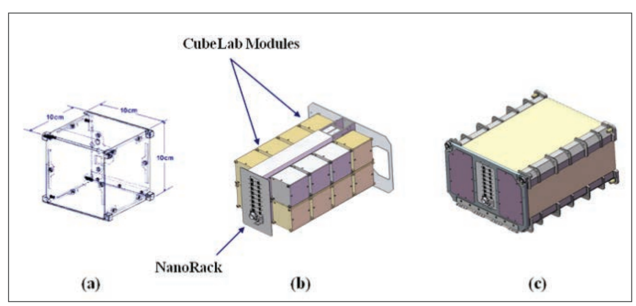
While the International Space Station (ISS) has proven its value as a platform for a broad waterfront of research disciplines as well as technology development, it also provides an ideal opportunity to test new business relationships. This allows an opportunity to shift from a paradigm of government-funded, contractor-provided goods and services to a commercially provided, government-as-a-customer approach.

This interest in promoting a more commercially oriented market in low-Earth orbit (LEO) is driven by several goals. First, it can stimulate entirely new markets not achievable in the past. Second, it creates new stakeholders in spaceflight and represents great economic opportunity. Third, it ensures strong industrial capability not only for future spaceflight but also for the many related industries. Finally, and perhaps most importantly, it allows cross-pollination of ideas, processes, and best practices, between partners of equal standing.

From commercial firms spending some of their research and development funds to conduct research on the space station, to commercial service providers selling unique services to users of the orbiting lab, the beginnings of a new economy in LEO is starting to emerge.



Various sizes of Cubelab modules are available. Image courtesy of NanoRacks.



Cubelabs fit within SubeLab Modules that will in turn fit into an EXPRESS Rack on the ISS. Image courtesy of NanoRacks.

Education

Students participating in STEM education training.

JAXA astronaut Koichi Wakata reads a book to students in the Cupola.

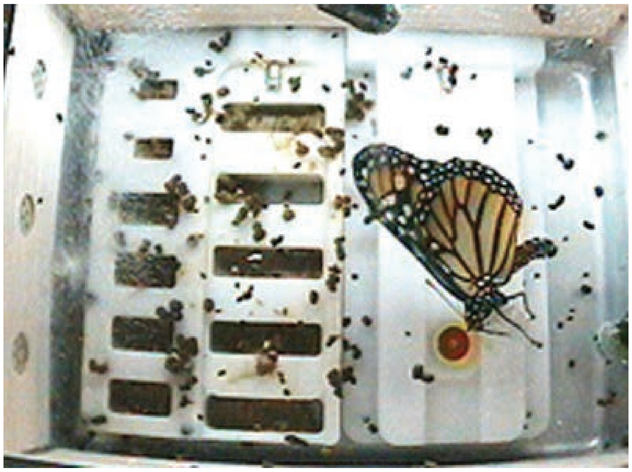
Students learning about different STEM opportunities at NASA.

The International Space Station has a unique ability to capture the interests of both students and teachers worldwide. The presence of humans onboard ISS has provided a foundation for numerous educational activities aimed at capturing that interest and motivating study in the sciences, technology, engineering and mathematics (STEM). Over 43 million students from 64 countries around the world have participated in ISS-related educational activities. Having the opportunity to connect with crewmembers real-time, either through"live" downlinks or simply speaking via a ham radio, ignites the imagination of students about space exploration and its application to the STEM fields. Projects such as Earth Knowledge-based Acquired by Middle Schools (EarthKAM) have allowed for global student, teacher and public access to space through student image acquisition. This serves to support inquiry-based learning which is an approach to science education that allows students to ask questions, develop hypothesis-derived experiments, obtain supporting evidence, analyze data, and identify solutions or explanations.

Through the life of ISS operations, these projects and their accompanying educational materials will continue to be made available to more students and more countries. Through expanded international cooperation, the next generation of scientists, engineers and explorers from our global community will have the capability to learn more about and be involved in space exploration.

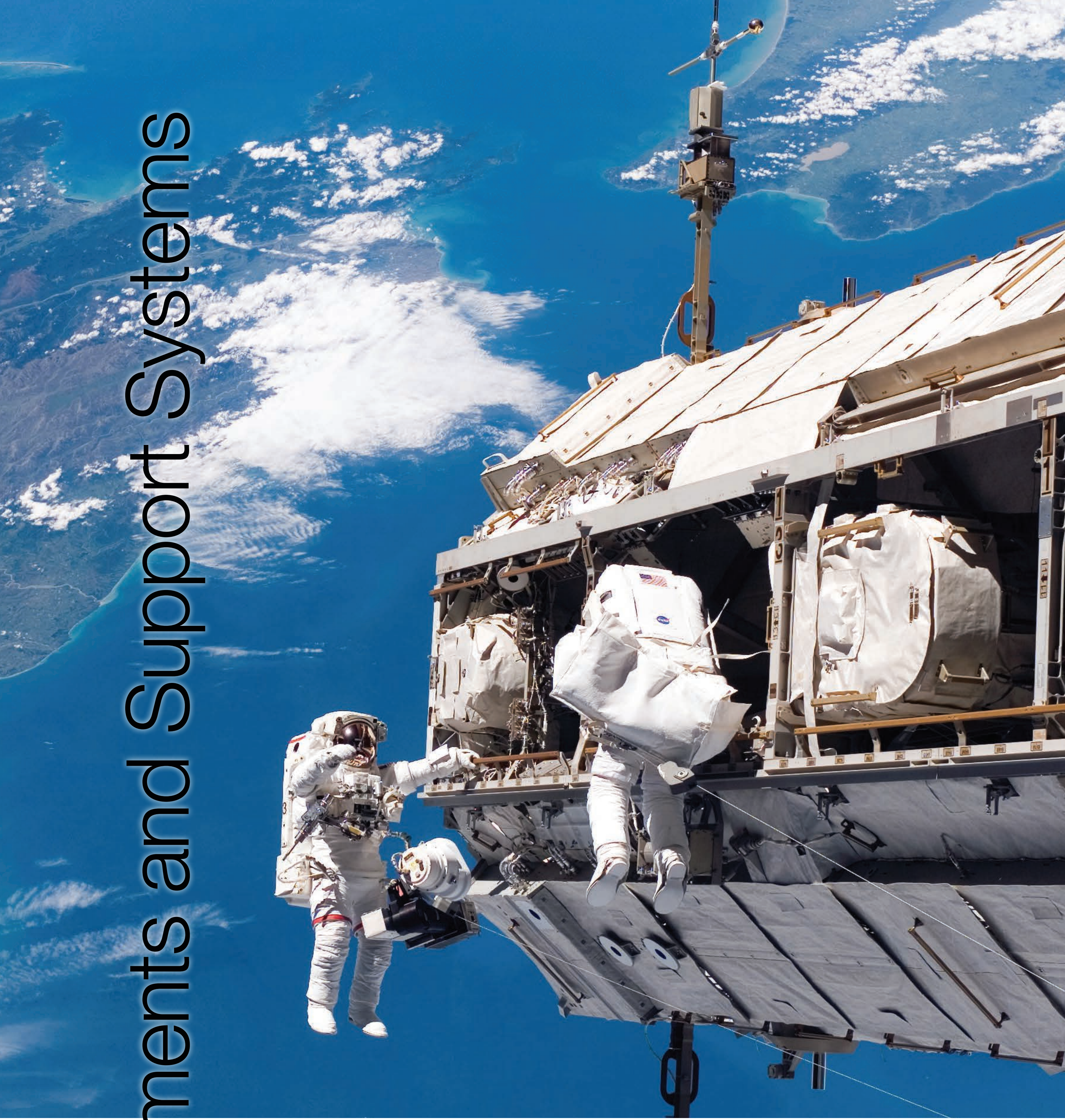
A Canadian student from Good Shepherd School in Peace River, Alberta, studies orbital paths of the International Space Station.

NASA Astronaut Scott Kelly poses with 600,000 tomato seeds for the Tomatosphere™ educational project.



After completing its pupa stage, a Monarch butterfly emerges on the International Space Station on Nov. 30, 2009 during the latest in a series of educational experiments designed to accompany in-class experiments for teachers and students.
Credit: NASA/BioServe, University of Colorado

Elements and Support Systems



The International Space Station modules serve as a habitat for its crew and provide ports for docking and berthing of visiting vehicles. The station functions as a microgravity and life sciences laboratory, test bed for new technologies, and platform for Earth and celestial observations.

U.S. Laboratory Module Destiny

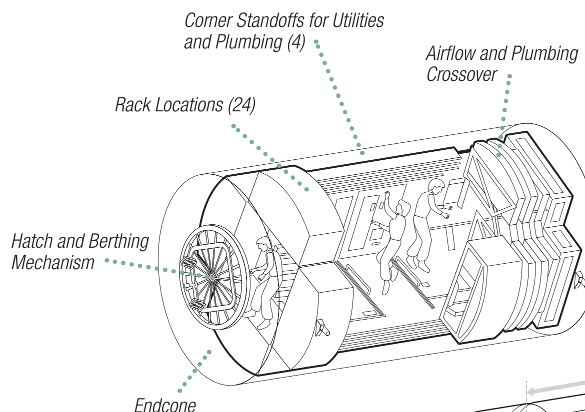
NASA/Boeing

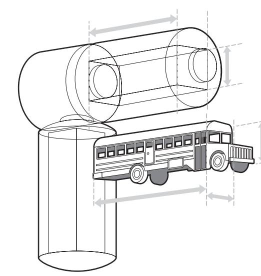
Length	8.5 m (28 ft)
Length with attached Common Berthing Mechanism (CBM)	9.2 m (30.2 ft)
Width	4.3 m diameter (14 ft)
Launch Mass	14,515 kg (32,000 lb)
Exterior	Aluminum, 3 cylindrical sections, 2 endcones
Number of racks	24 (13 scientific and 11 system)
Windows	1, with a diameter of 50.9 cm (20 in)
Launch date	February 7, 2001 STS-98 5A

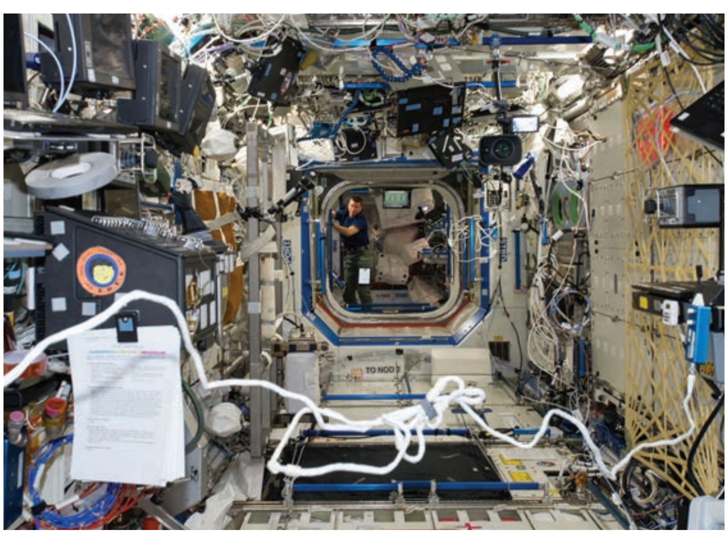
The U.S. Laboratory Module, called Destiny, is the primary research laboratory for U.S. payloads, supporting a wide range of experiments and studies contributing to health, safety, and quality of life for people all over the world.

Science conducted on the ISS offers researchers an unparalleled opportunity to test physical processes in the absence of gravity. The results of these experiments will allow scientists to better understand our world and ourselves and prepare us for future missions. Destiny provides internal interfaces to accommodate 24 equipment racks for accommodation and control of ISS systems and scientific research.

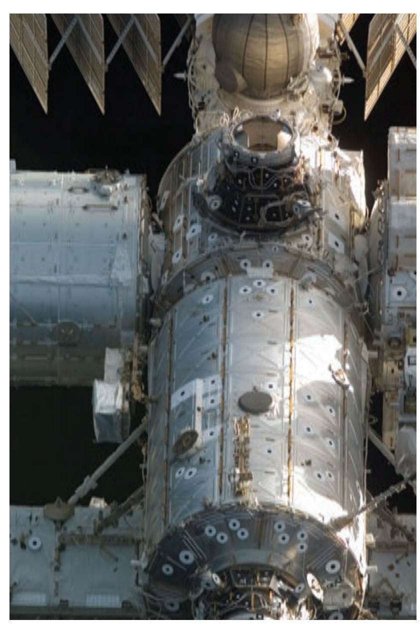
NASA astronaut Doug Wheelock as he retrieves 2D Nano Template sample bags from the Minus Eighty Laboratory Freezer for ISS (MELFI) in U.S. Laboratory Destiny.







NASA astronaut Reid Wiseman is pictured in the Harmony node looking through the Destiny laboratory.



Visible are the Pressurized Mating Adapter 2 (PMA2),Destiny laboratory module,and Node 1.

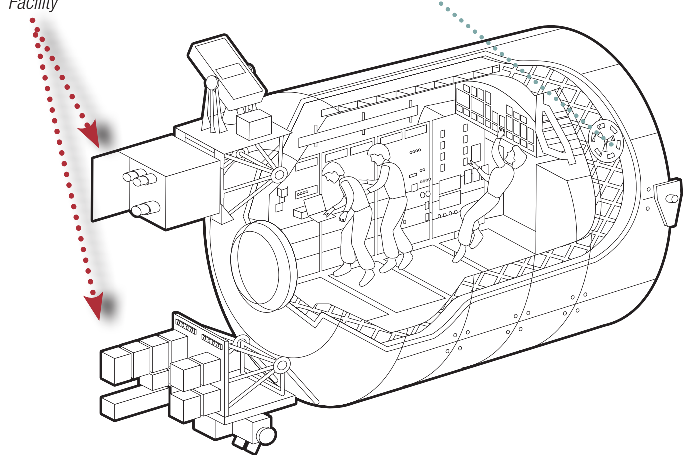
European Research Laboratory Columbus

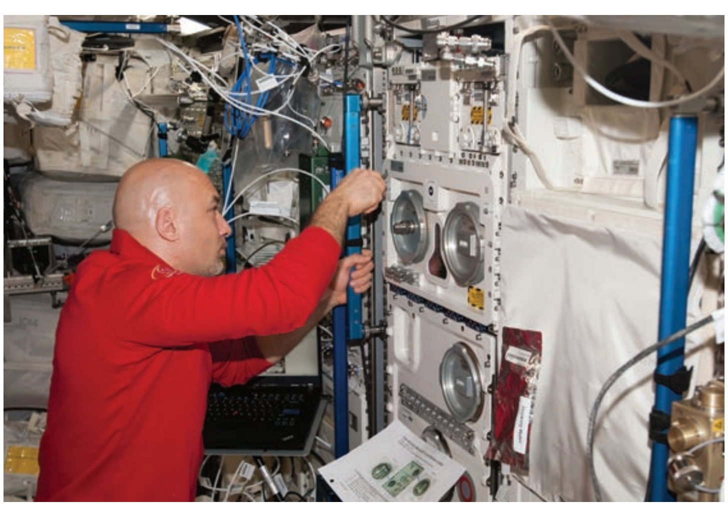
European Space Agency (ESA)/European Aeronautic Defence and Space Co. (EADS) Space Transportation

Length	6.9 m (22.6 ft)
Diameter	4.5 m (14.7 ft)
Launch Mass	10,300 kg (22,700 lb)
Launch date	February 7, 2008 STS-122 1E
Racks	10 International Standard Payload Racks (ISPRs)

The Columbus Research Laboratory is Europe's largest contribution to the International Space Station. Columbus is a multifunctional pressurized laboratory permanently attached to Node 2 of the ISS. The Columbus laboratory's flexibility provides room for the researchers on the ground, aided by the station's crew, to conduct thousands of experiments in life sciences, materials sciences, fluid physics and other research in a weightless environment not possible on Earth. In addition, experiments and applications can be conducted outside the module within the vacuum of space, thanks to four exterior mounting platforms that can accommodate external payloads in space science, Earth observation and technology.

An interior view of the Columbus laboratory of the International Space Station.





ESA astronaut Luca Parmitano works with the Biolab in the Columbus laboratory of the International Space Station. Biolab is used to perform space biology experiments on microorganisms, cells, tissue cultures, plants and small invertebrates.

Columbus attached to the ISS.

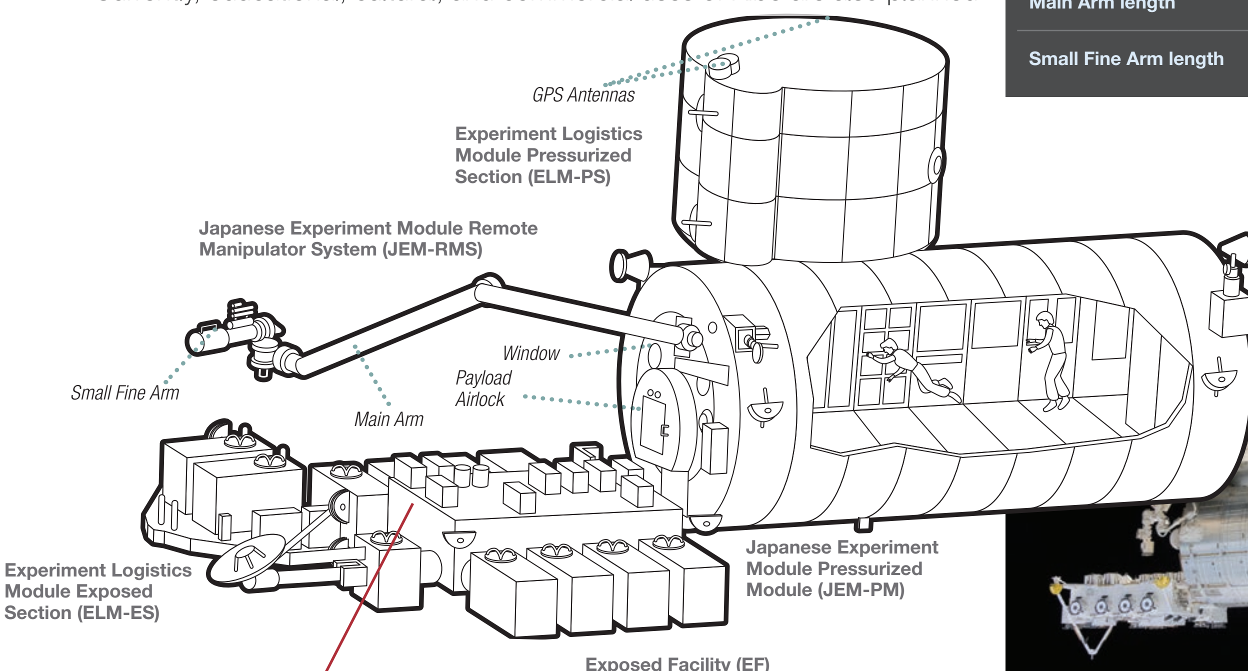
Japanese Experiment Module Kibo (Hope)

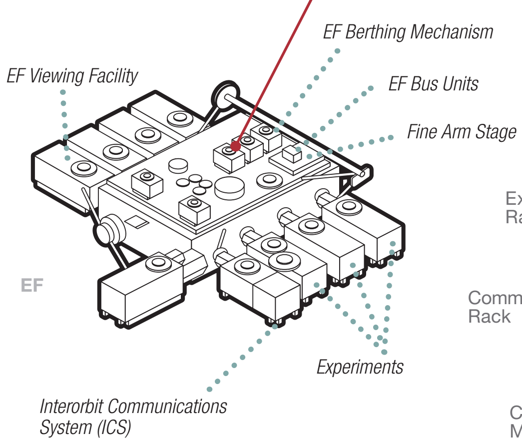
Japan Aerospace Exploration Agency (JAXA)/ Mitsubishi Heavy Industries, Ltd.

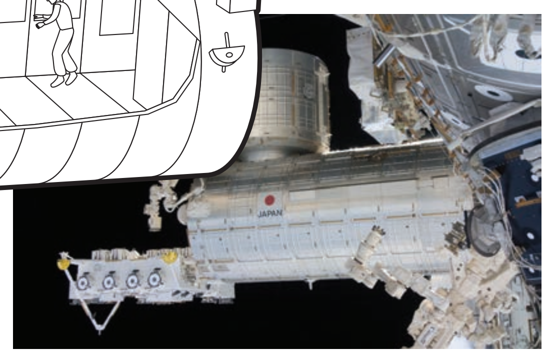
The Japanese Experiment Module (JEM), known as “Kibo” (pronounced key-bow), which means “hope” in Japanese, is Japan’s human-rated space facility and the Japan Aerospace Exploration Agency’s (JAXA’s) first contribution to the ISS program.

Kibo was designed and developed with a view to conducting scientific research activities on orbit. Thus, as a part of the ISS, Kibo provides extensive opportunities for utilization of the space environment performing experimental activities. Resources necessary for Kibo’s on-orbit operation, such as air, power, data, and cooling fluid, are provided from the U.S. segment of the ISS. Currently, educational, cultural, and commercial uses of Kibo are also planned.

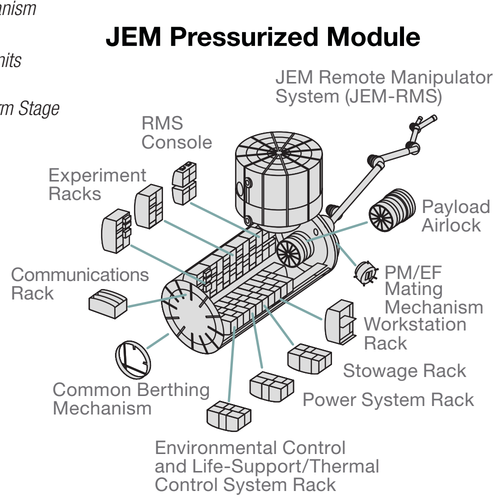
	PM	ELM-PS
Diameter	4.4 m (14.4 ft)	4.4 m (14.4 ft)
Length	11.2 m (36.7 ft)	4.2 m (13.9ft)
Launch Mass	15,900 kg (35,050 lb)	4,200 kg (9,260 lb)
Launch date	May 31, 2008 STS-124 1J	March 11, 2008 STS-123 1J/A
EF		
Dimensions	5.6 × 5 × 4 m (18.4 × 16.4 × 13.1 ft)	
Launch Mass	4,100 kg (9,038 lb)	
Launch date	July 15, 2009 STS-127 2J/A	
JEM Remote Manipulator System		
Main Arm length		10 m (32.9 ft)
Small Fine Arm length		2.2 m (7.3 ft)







View of the Japanese Experiment Module (JEM) Pressurized Module (JPM),Japanese Experiment Logistics Module-Pressurized Section (JLP),and JEM Exposed Facility (JEF).

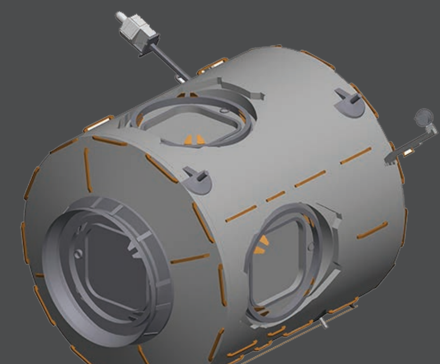


NASA astronauts Scott Kelly (left) and Terry Virts (right) work on a Carbon Dioxide Removal Assembly (CDRA) inside the station’s Japanese Experiment Module.

Nodes

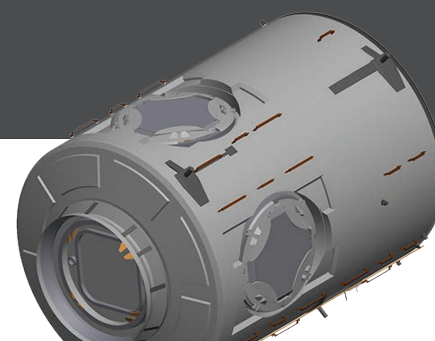
Nodes are U.S. modules that connect the elements of the ISS. Node 1, called Unity, was the first U.S.-built element that was launched, and it connects the U.S. and Russian segments.

Node 2 (Harmony) and Node 3 (Tranquility) are European-built elements and are each one rack bay longer than Node 1. Node 2 connects the U.S., European, and Japanese laboratories, as well as providing a nadir berthing port and a forward PMA-2 docking port. Node 3 is attached to the port side of Node 1 and provides accommodation for life-support and exercise equipment.

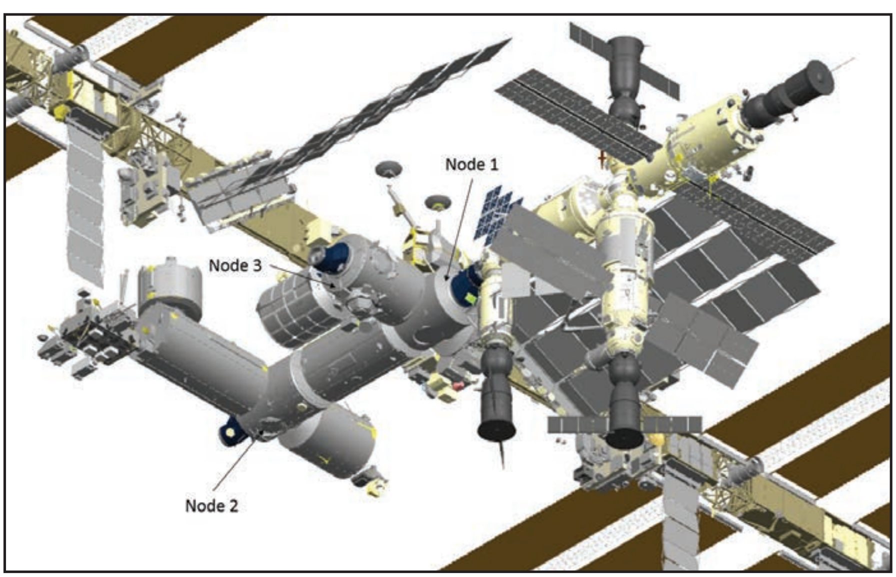


Node 1

Astronaut Reid Wiseman is photographed at work in the Node 2 module. He is joined by Astronaut Steve Swanson (left).



Node 2

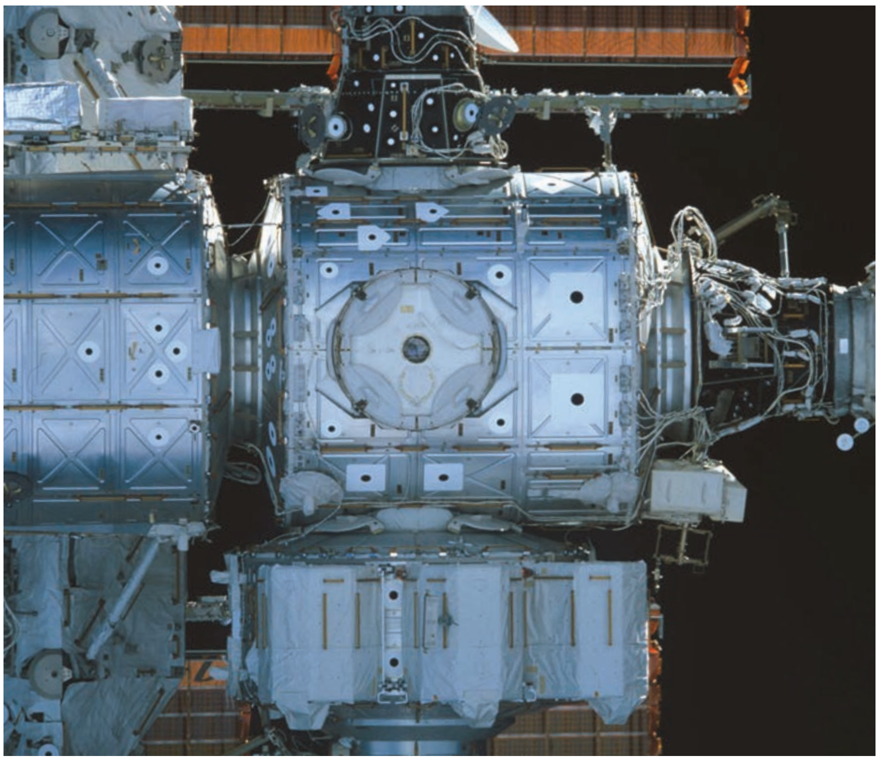


Node 3

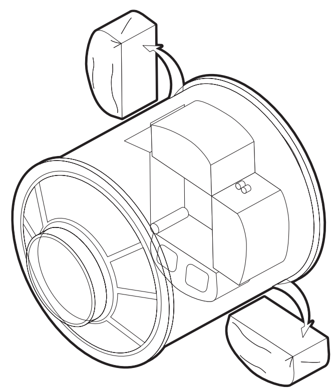
Node 1
Unity
NASA/Boeing

Length	5.5 m (18 ft)
Width (diameter)	4.3 m (14 ft)
Mass	11,895 kg (26,225 lb)
Exterior	Aluminum cylindrical sections, 2 endcones
Number of racks	4
Launch date	December 4, 1998 STS-88 2A

Node 1's six ports provide berthing connections to the Z1 Truss, U.S. Laboratory Module, Airlock, Node 3 and PMA/FGB. In the summer of 2015, the Node 1 nadir port will be available as a second berthing port for visiting cargo vehicles.



Node 1 is shown with the Russian segment FGB to the right (aft), the U.S. Laboratory to the left (fore), the U.S. Airlock at the bottom (starboard), and PMA-3 at the top (port).



Placement of racks in Node 1.

NASA astronaut Karen Nyberg is pictured near fresh fruit floating freely in the Unity Node 1 module.

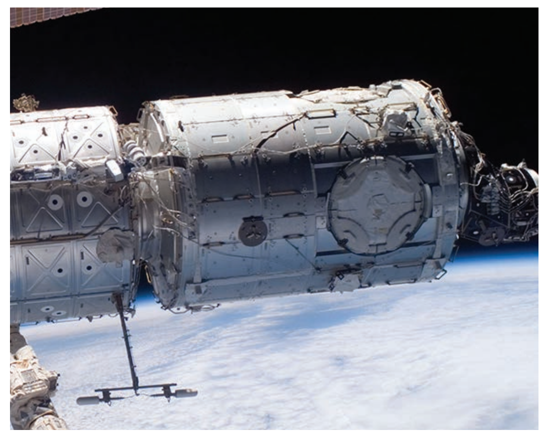
The moments are far and few between when crewmembers have an opportunity to gather together. Pictured here in Node 1 are Chris Hadfield of the Canadian Space Agency at the right. Clockwise from his position are the five flight engineers -- NASA astronauts Tom Marshburn and Chris Cassidy, and Russian cosmonauts Alexander Misurkin, Roman Romanenko and Pavel Vinogradov.

Node 2
Harmony

NASA/ESA/Thales Alenia Space Italy (TAS-I)

Length	6.7 m (22 ft)
Width (diameter)	4.3 m (14 ft)
Mass	14,787 kg (32,599 lb)
Exterior	Aluminum cylindrical sections, 2 endcones
Number of racks	8
Launch date	October 23, 2007 STS-120 10A

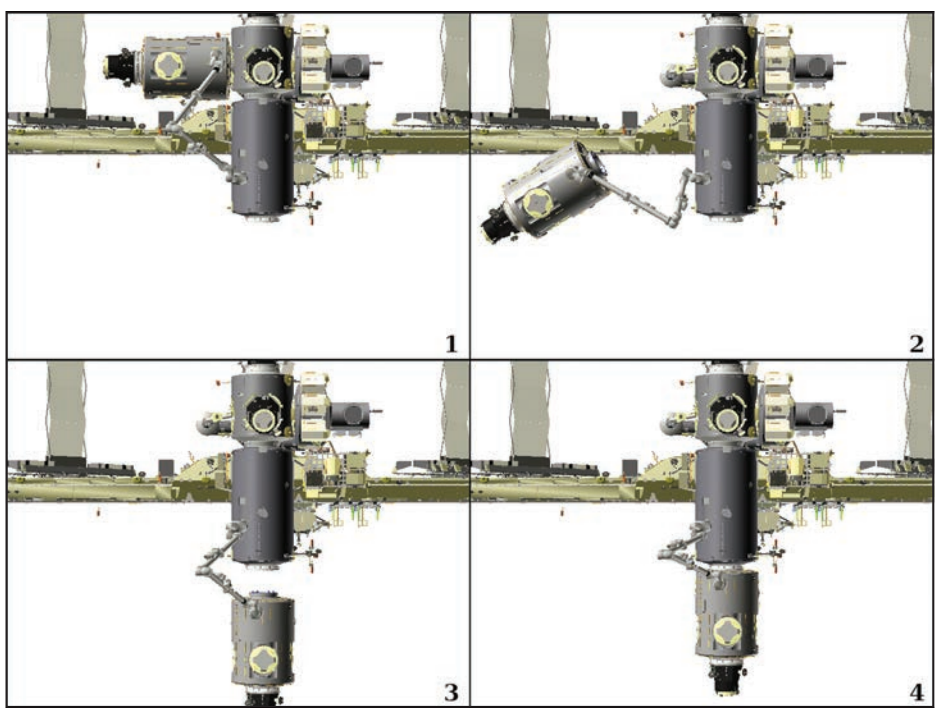
Node 2 was built in Europe by Thales Alenia Space Italy (TAS-I) under contract of the European Space Agency. It incorporates six berthing ports: two in the longitudinal axis and four on the radial perpendicular axes. Node 2 is attached to the forward end of the U.S. laboratory and connects Columbus, the European laboratory, on the starboard side; Kibo, the Japanese laboratory, on the port side; the Pressurized Mating Adaptor 2 (PMA-2) on the forward side, which provides a docking location for visiting vehicles. On the nadir (Earth-facing) side, Node 2 provides a berthing port for the H-II Transfer Vehicle (HTV), a Japanese cargo vehicle as well as commercial cargo vehicles,. In the summer of 2015, the PMA3 (currently on Node 3) will be relocated to provide a second U.S. docking port on the zenith port of Node 2. In addition, Node 2 provides crew quarters for 4 crew members as well as vital functional resources for the operation of the connected elements, namely the conversion and distribution of the electrical power, heating, cooling resources from the ISS Integrated Truss, and support of the data and video exchange with the ground and the rest of the ISS.



Exterior view of Node 2.

ESA astronaut Samantha Cristoforetti works on the Maintenance Work Area (MWA) which provides a rigid surface on which to perform maintenance tasks.

ESA astronaut Alexander Gerst conducts a session with the Capillary Flow Experiment (CFE-2) in the Harmony Node 2.



Initially Node 2 was berthed on the starboard port of Node 1. The ISS's remote manipulator moved Node 2 to the forward port of the U.S. Lab. PMA2 is berthed to the front port of Node 2.

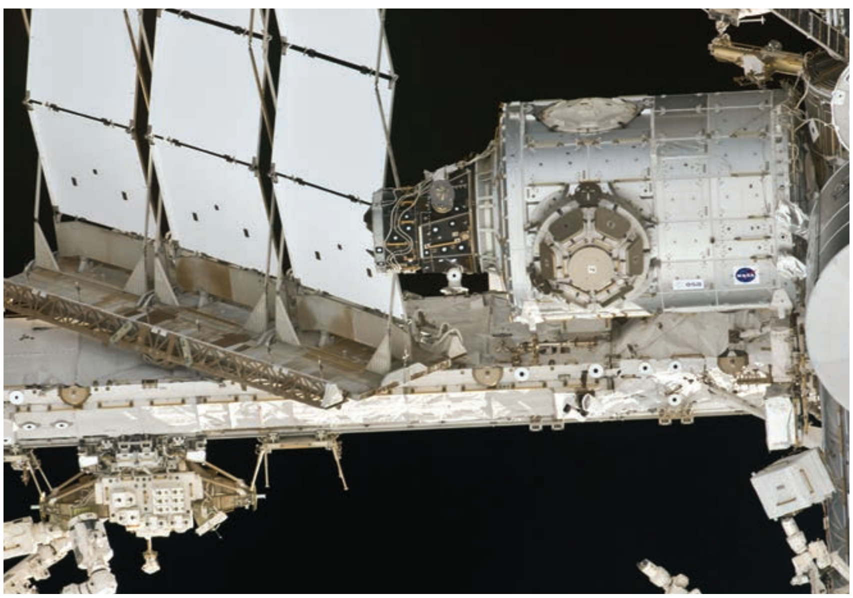
Node 3 Tranquility

NASA/ESA/Thales Alenia Space Italy (TAS-I)

Node 3 was built in Europe by Thales Alenia Space Italy (TAS-I) under contract of the European Space Agency. Node 3 is attached to the port side of Node 1, and the Cupola is berthed on its nadir (Earth facing) port. The PMA-3 is currently attached to the Node 3 port. The zenith port has been inhibited and modified to become the parking location for the Special Purpose Dexterous Manipulator (SPDM). In the summer of 2015, the PMM will be relocated from the Node 1 nadir port to the Node 3 forward port and the PMA-3 will be relocated to Node 2 zenith port. The port and aft ports are then available for further ISS additions.

Node 3 accommodates ISS air revitalization, oxygen generation, carbon dioxide removal and water recovery systems. It also contains the bathroom for the crew hygiene and exercising equipment such as a treadmill and a weight-lifting device.

Length	6.7 m (22 ft)
Width (diameter)	4.3 m (14 ft)
Mass	17,992 kg (39,665 lb)
Exterior	Aluminum cylindrical sections, 2 endcones
Number of racks	8
Launch dates	February 8, 2010 STS-130 20A



Exterior view of the P1 truss segment, Node 3/Tranquility and Cupola.

View of the Waste Management Compartment (WMC) in the Node 3 module.

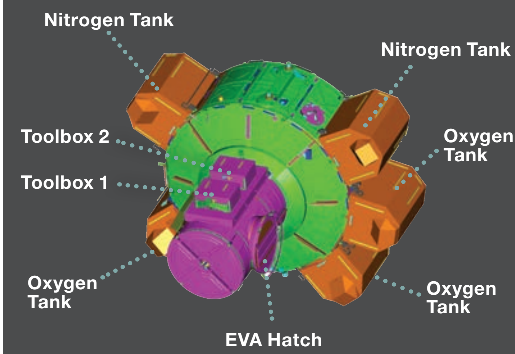
NASA astronaut Chris Cassidy enters data in a computer in the Tranquility node.

Interior view of the Node 3/Tranquility.

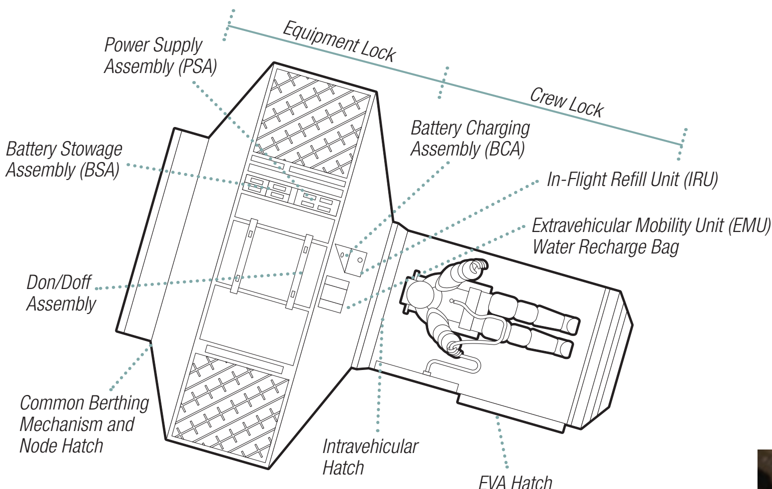
Joint Airlock Quest

NASA/Boeing

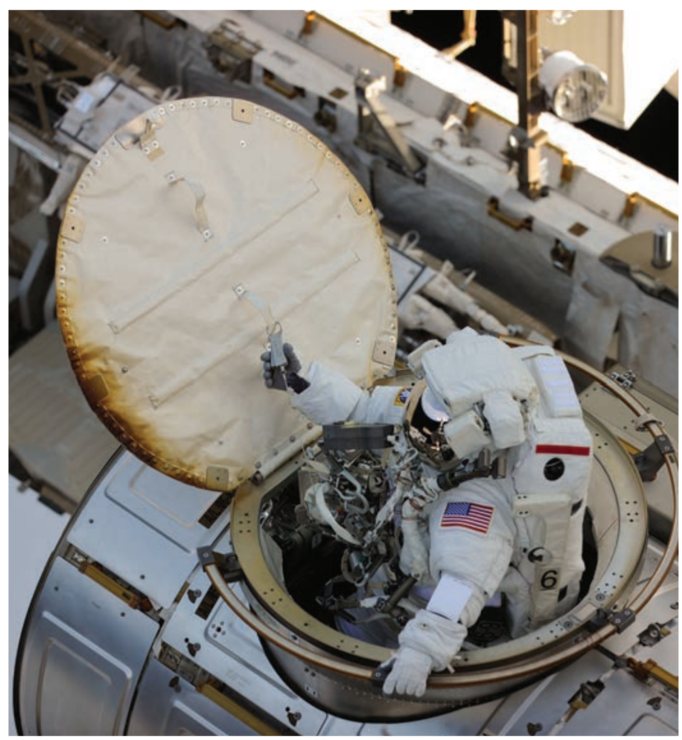
Length	5.5 m (18 ft)
Width	4.0 m (13.1 ft)
Mass	9,923 kg (21,877 lb)
Launch date	July 12, 2001 STS-104 7A



The Quest Airlock is a pressurized space station module consisting of two compartments attached end-to-end by a connecting bulkhead and hatch. The two compartments consist of: the Equipment Lock, which provides the systems and volume for suit maintenance and refurbishment, and the Crew Lock, which provides the actual exit for performing EVAs. The airlock is the primary path for International Space Station spacewalk entry and departure for U.S. spacesuits, which are known as Extravehicular Mobility Units, or EMUs. Quest can also support the Russian Orlan spacesuit for spacewalks.



View of NASA astronaut Chris Cassidy (left) and ESA astronaut Luca Parmitano (right) preparing for a dry run in the International Space Stations Quest airlock in preparation for the first of two sessions of extravehicular activity. Both are wearing a liquid cooling and ventilation garment and preparing to don their EMUs. Astronaut Karen Nyberg, is visible in the foreground.



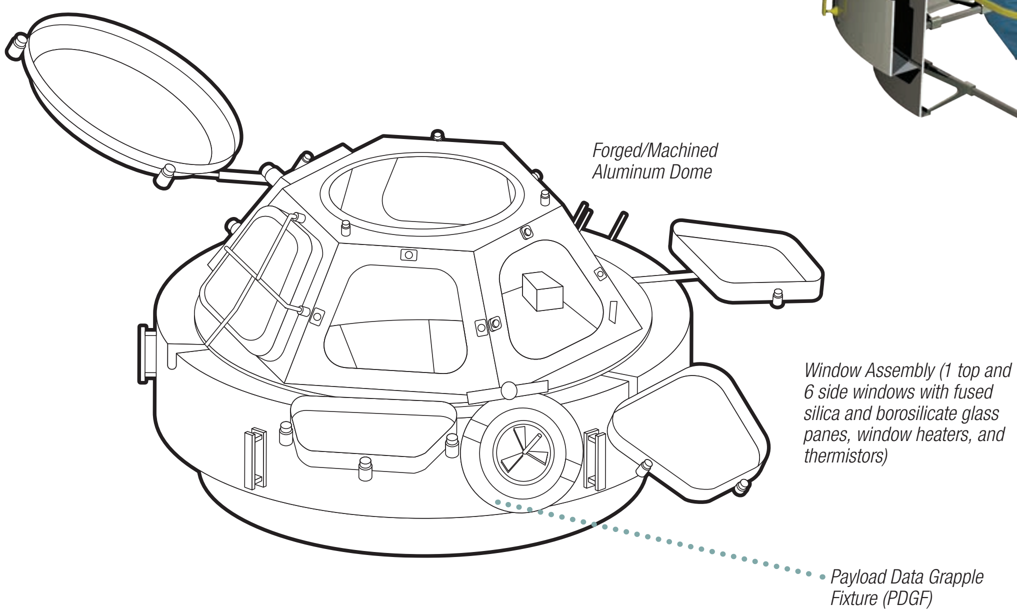
NASA astronaut Doug Wheelock enters the Quest airlock as the session of extravehicular activity draws to a close.

Cupola

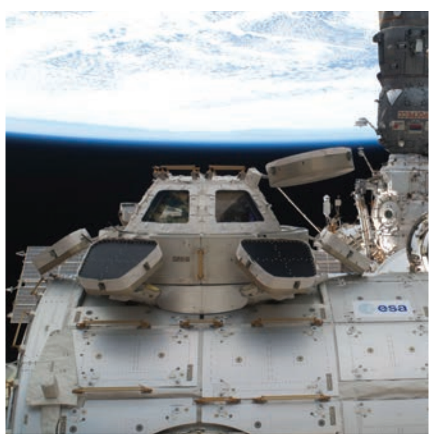
NASA/ESA/Thales Alenia Space Italy (TAS-I)

Height	1.5 m (4.7 ft)
Diameter	3 m (9.8 ft)
Mass	1,880 kg (4,136 lb)
Capacity	2 crewmembers with portable workstation
Launch date	February 8, 2010 STS-130 20A

The Cupola (named after the raised observation deck on a railroad caboose) is a small module designed for the observation of operations outside the ISS such as robotic activities, the approach of vehicles, and extravehicular activity (EVA). It was built in Europe by Thales Alenia Space Italy (TAS-I) under contract of the European Space Agency. It provides spectacular views of Earth and celestial objects. The Cupola has six side windows and a direct nadir viewing window, all of which are equipped with shutters to protect them from contamination and collisions with orbital debris or micrometeorites. The Cupola is designed to house the robotic workstation that controls the ISS's remote manipulator arm. It can accommodate two crewmembers simultaneously and is berthed to the Earth facing side of Node-3 using a Common Berthing Mechanism (CBM).



At the robotics workstation in the Cupola, NASA astronaut Karen Nyberg participates in onboard training activity in preparation for the grapple and berthing of a visiting vehicle.



Exterior view of the Cupola and the Node 3/Tranquility taken by a crew member during a Extravehicular Activity (EVA). Crew members onboard are partially visible in the Cupola windows.

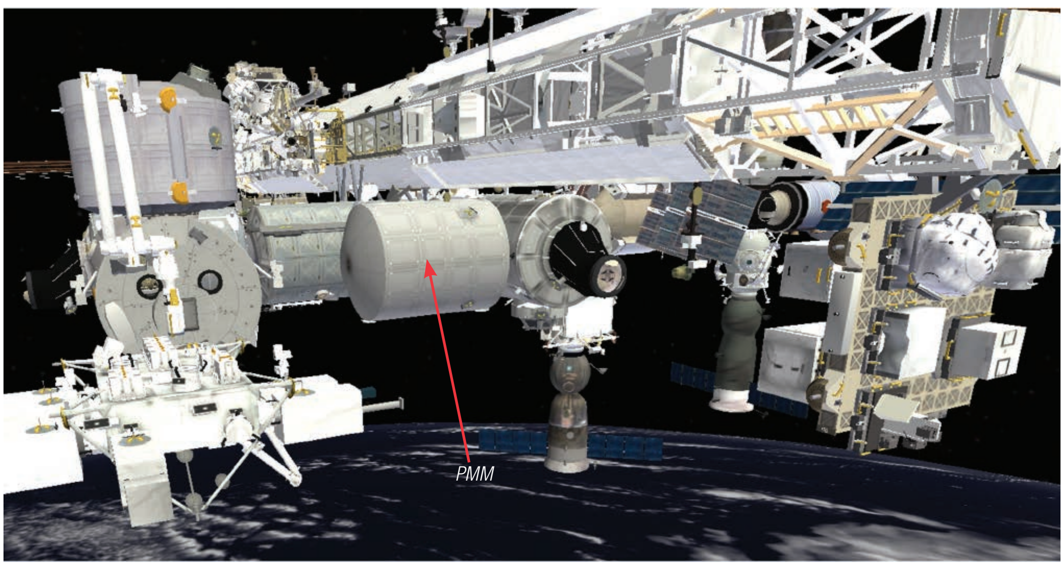
ESA astronaut Alexander Gerst enjoys the view of Earth from the windows in the Cupola of the International Space Station.

Permanent Multipurpose Module (PMM)

NASA/ASI (Italian Space Agency)

Derived from the Leonardo Multi-purpose Logistics Module (MPLM), the Italian-built Permanent Multi-Purpose Module (PMM) is currently berthed to the nadir port of Node 1. In the summer of 2015, the PMM will be relocated to the Node 3 forward port. The PMM can host up to 16 racks containing equipment, experiments, and supplies, and it has additional storage space for bags in the aft endcone.

Length	6.67 m (21.7 ft)
Diameter Exterior Interior	 4.5 m (14.76 ft) 4.21 m (13.81 ft)
Mass	4,428 kg (9,784 lb)
Pressurized volume	76.7 m³ (2708.6 ft³)
Cargo capability	9,000 kg (20,000 lb)
Pressurized habitable volume	31 m³ (1,095 ft³)



NASA astronauts Chris Cassidy and Karen Nyberg along with ESA astronaut Luca Parmitano are shown amongst cargo bags in the PMM.

View of Permanent Multipurpose Module (PMM) and Soyuz spacecraft.

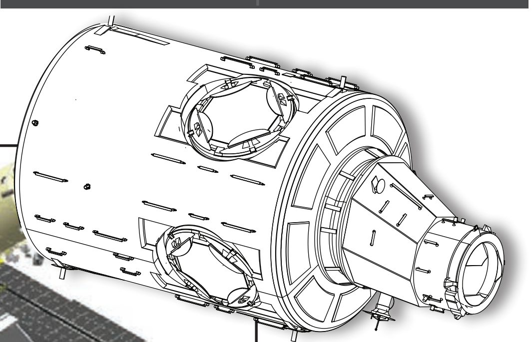
Pressurized Mating Adapters (PMAs)

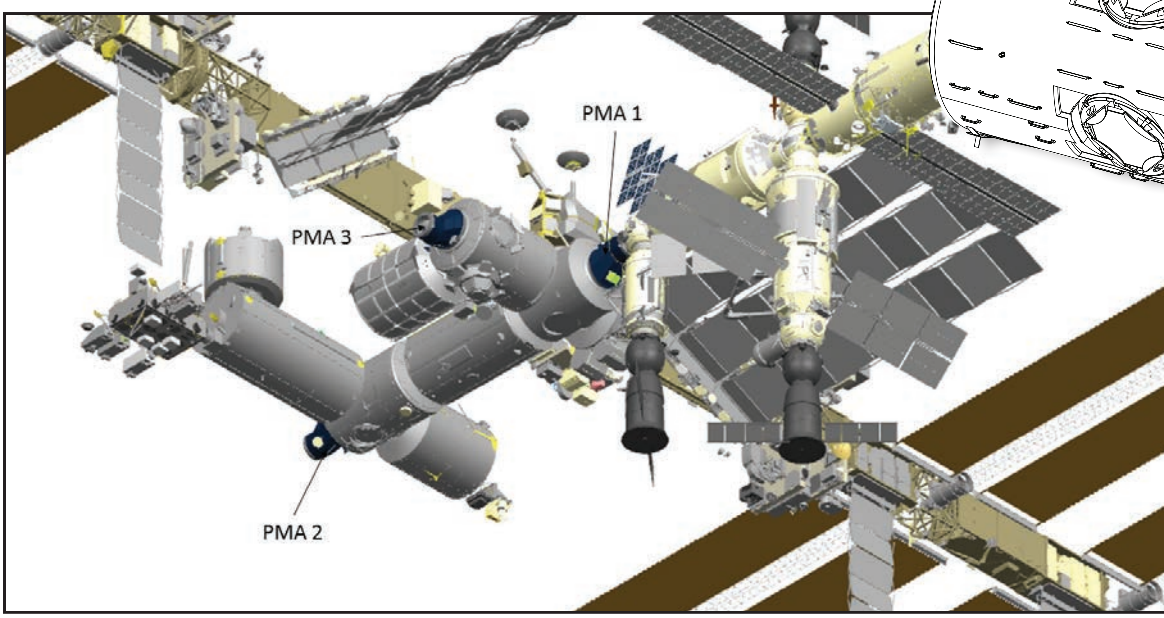
NASA/Boeing

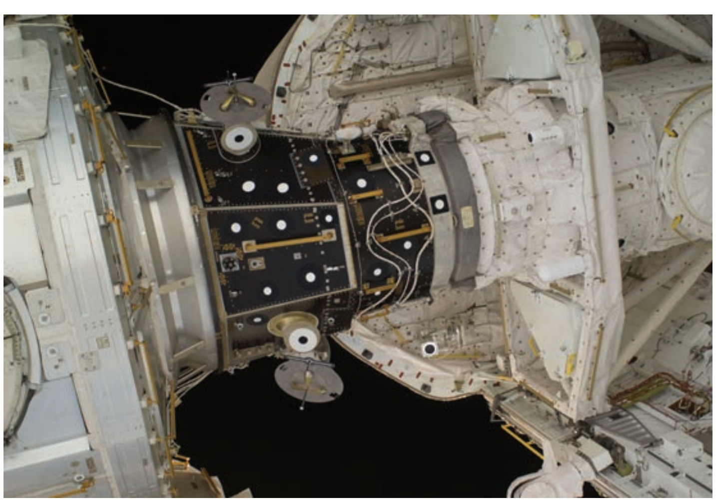
Length	1.86 m (6.1 ft)
Width	1.9 m (6.25 ft) at wide end, 1.37 m (4.5 ft) at narrow end
Mass of	
PMA-1	1,589 kg (3,504 lb)
PMA-2	1,376 kg (3,033 lb)
PMA-3	1,183 kg (2,607 lb)
Launch date	
PMAs 1 and 2	December 4, 1998 STS-88 ISS-2A
PMA-3	October 11, 2000 STS-92 ISS-3A

Three conical docking adapters, called Pressurized Mating Adapters, attach to the Nodes' berthing mechanisms. The other sides of the adapters allow for docking vehicles. PMA-1 connects the U.S. and Russian segments while PMA-2 and PMA-3 serve as docking ports for future commercial crew vehicles. PMA-2 is located on the Node 2 forward port and PMA-3 is currently located on Node 3 port. In the summer of 2015 PMA-3 will be relocated to the Node 2 zenith port. The ISS at that point will have two permanent docking ports.

PMA-1, 2 and 3 structures are identical. The PMA structure is a truncated conical shell with a 28 inch axial offset in the diameters between the end rings.







View of Node 2, Pressurized Mating Adapter 2 (PMA-2) taken during Extravehicular Activity (EVA).

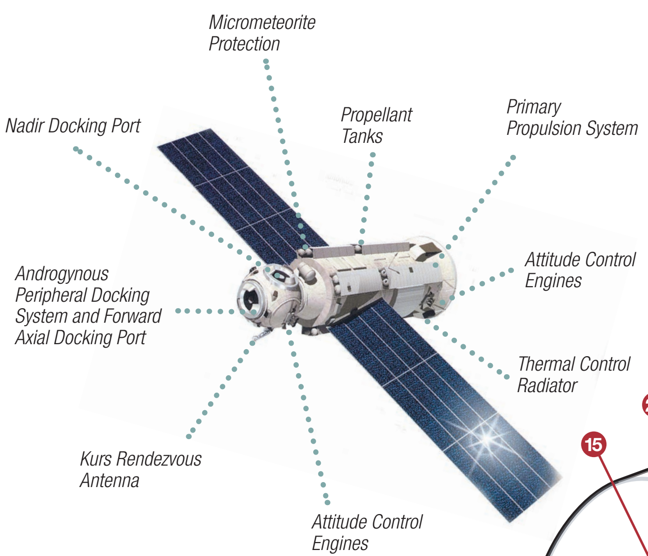
ESA astronaut Paolo Nespoli and NASA astronaut Ron Garan pause for a photo during preparations to open the Pressurized Mating Adapter 2 (PMA-2) hatch.

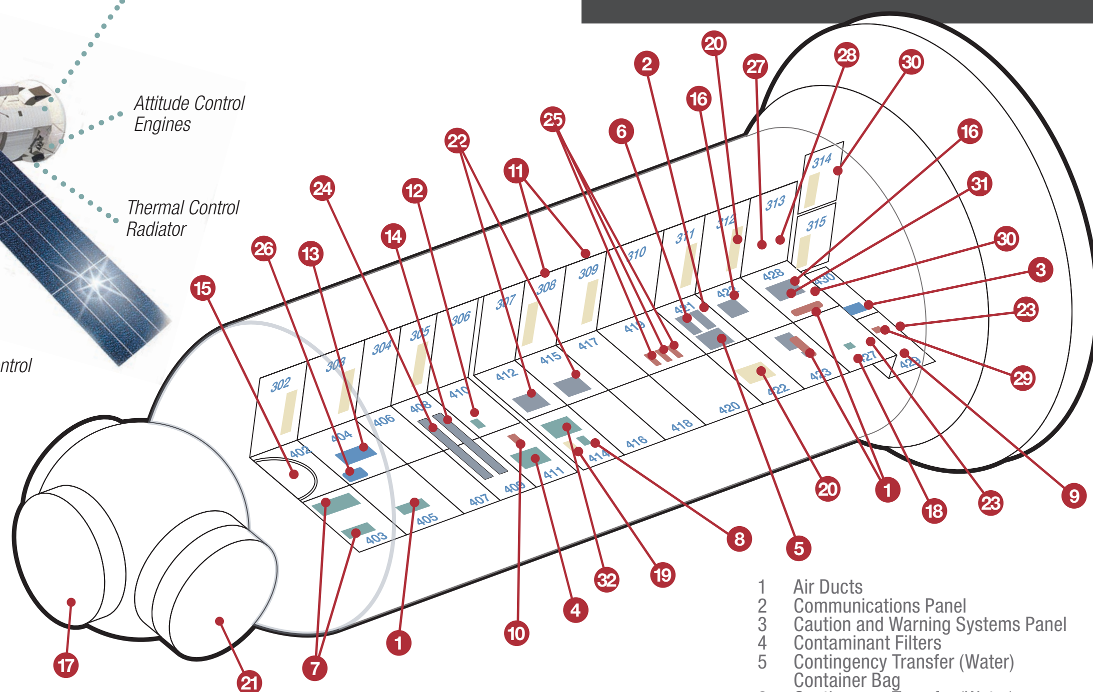
Functional Cargo Block (FGB) Zarya (Sunrise)

NASA/Boeing/Khrunichev State Research and Production Space Center

Length	12,990 m (42.6 ft)
Maximum diameter	4.1 m (13.5 ft)
Mass	24,968 kg (55,045 lb)
Pressurized volume	71.5 m³ (2,525 ft³)
Solar array span	24.4 m (80 ft)
Array surface area	28 m² (301 ft²)
Power supply (avg.)	3 kW
Propellant mass	3,800 kg (8,377 lb)
Launch date	November 20, 1998 Proton rocket 1A/R

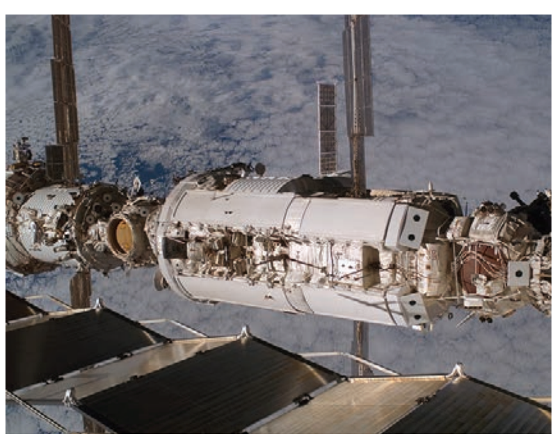
The FGB was the first launched element of the ISS, built in Russia under a U.S. contract. During the early stages of ISS assembly, the FGB was self-contained, providing power, communications, and attitude control functions. Now, the FGB module is used primarily for storage and propulsion. The FGB was based on the modules of Mir.





1 Air Ducts
2 Communications Panel
3 Caution and Warning Systems Panel
4 Contaminant Filters
5 Contingency Transfer (Water) Container Bag
6 Contingency Transfer (Water) Container Connections
7 Dust Collectors
8 Electrical Outlet
9 Flex Airduct Container
10 Fuse
11 Fuse Panels (behind close-outs)
12 Gas Analyzer
13 Gas Mask
14 Handrail
15 Hatch Protection
16 Instrument Containers
17 Docking Port to PMA
18 Laptop Outlets
19 Lighting Panel
20 Lights
21 Nadir Docking Port
22 Onboard Documentation
23 Onboard Network Receptacle Outlets
24 Pole and Hook
25 Portable Fans
26 Removable Fire Extinguisher
27 Power Outlet
28 Pressurized Valve Unit
29 Caution and Warning Panel
30 Smoke Detector
31 TV Outlet
32 Wipes/Filters

Russian cosmonaut Maxim Suraev using the communications system in the FGB.



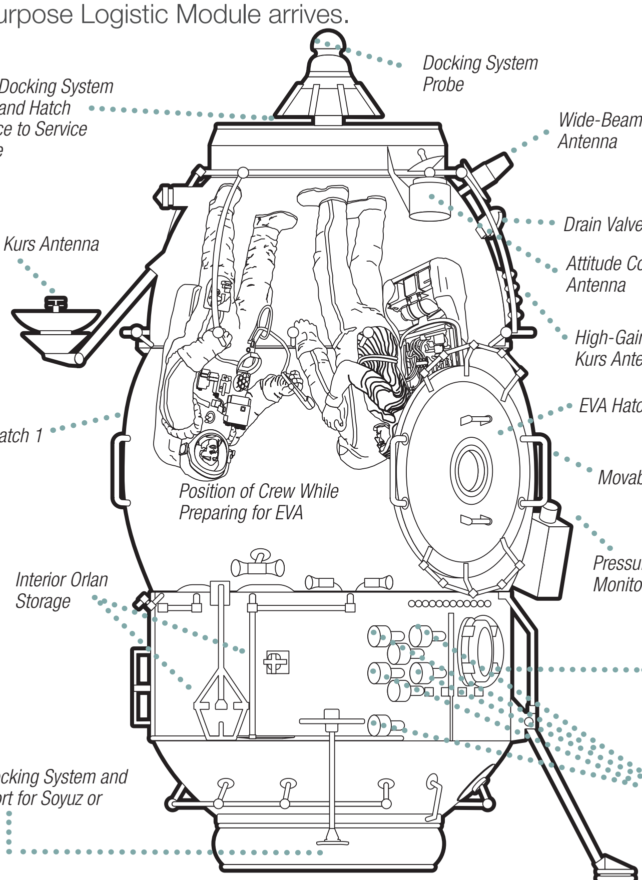
View of the FGB on orbit flanked by the Service Module and PMA-1.

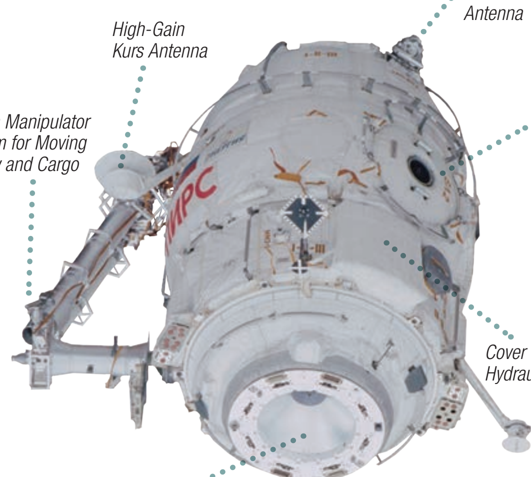
Docking Compartment (DC) Pirs (Pier)

Russian Federal Space Agency (Roscosmos)/ S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

Length	4.9 m (16 ft)
Maximum diameter	2.55 m (8.4 ft)
Mass	3,838 kg (8,461 lb)
Volume	13 m³ (459 ft³)
Launch date	September 15, 2001 Progress M 4R

Pirs serves as a docking port for the Russian Segment. Pirs also provides the capability for extravehicular activity (EVA) using Russian Orlan spacesuits and provides systems for servicing and refurbishing of the spacesuits. The nadir Docking System on Pirs provides a port for the docking of Soyuz and Progress vehicles. Pirs will be deorbited when the final Russian Multi-Purpose Logistic Module arrives.





View of the nadir end of the DC.

Cosmonaut Oleg Kononenko with two Russian Orlan spacesuits in the Pirs Docking Compartment.

Progress supply vehicle docked to the Pirs DC-1.

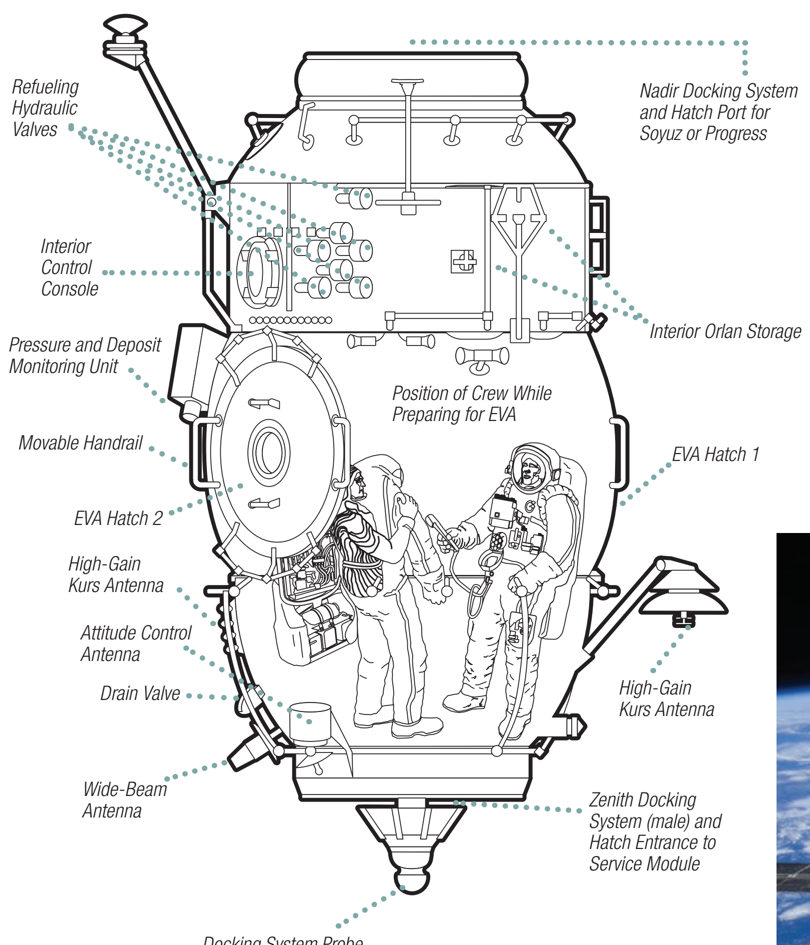
Mini-Research Module 2 (MRM2) Poisk (Explore)

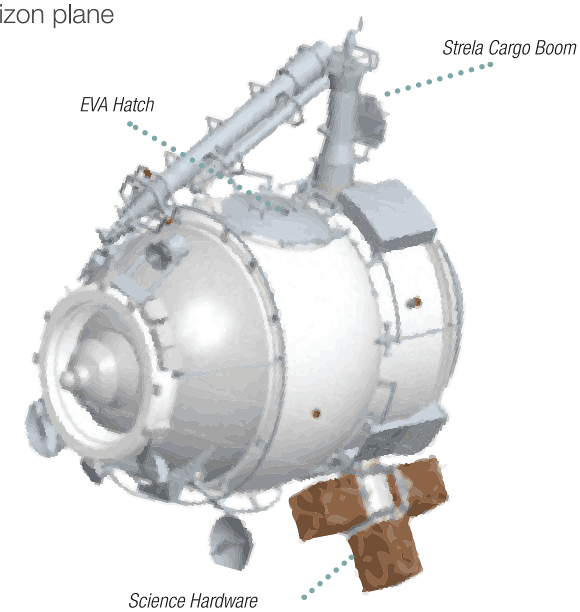
Russian Federal Space Agency (Roscosmos)/ S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

Length	4.9 m (16 ft)
Maximum diameter	2.55 m (8.4 ft)
Mass	3,795 kg (8,367 lb)
Volume	14.8 m³ (523 ft³)
Launch date	November 10, 2009 Progress M 5R

Poisk, also known as the MRM2, is almost identical to the Pirs Docking Compartment. Poisk provides the capability for extravehicular activity (EVA) and servicing/refurbishing of the Russian Orlan spacesuits.

The zenith docking system on Poisk provides a port for the docking of Soyuz and Progress logistics vehicles. Poisk also provides extra space for scientific experiments, including power supply outlets and data transmission interfaces for five external workstations (one three-port active and four passive) to accommodate science payloads for observation of the upper hemisphere and for exposure. The module is also equipped with three temporary internal workstations near the module's side windows to observe a local horizon plane and to accommodate payloads equipped with vacuum interfaces.





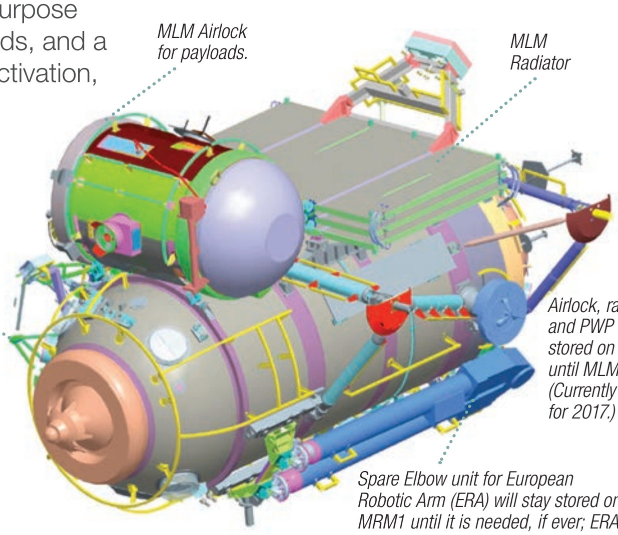
Exterior view of the Mini Research Module 2 (MRM2)/Poisk.

Mini-Research Module 1 (MRM1) Rassvet (Dawn)

Russian Federal Space Agency (Roscosmos)/ S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

Length	6.0 m (19.7 ft)
Maximum diameter	2.35 m (7.7 ft)
Mass	5,075 kg (11,188 lb)
Volume	17.4 m³ (614 ft³)
Launch date	May 2010 STS-132 ULF4
Attitude control	32 engines
Orbital maneuvering	2 engines

Rassvet, also known as the MRM1, is primarily used for cargo storage; being equipped with eight internal workstations. It serves as a mini-research laboratory for biological and biotechnological investigations, as well as for experiments in material sciences and fluid physics. The nadir docking system on Rassvet provides the fourth docking port on the Russian segment for the docking of Soyuz and Progress logistics vehicles. It was built from the pressurized hull of the Science Power Platform (SPP) dynamic test article. Moreover, the exterior of Rassvet carries a spare elbow joint for the European Robotic Arm (ERA) and outfitting equipment for the Russian Multi-Purpose Laboratory Module (MLM), including a radiator, an airlock for payloads, and a Portable Work Post (PWP) that provides an EVA worksite for ERA activation, checkout, and nominal operations.



View of the Rassvet Mini-Research Module 1 (MRM1) as it is mated with the Zarya Functional Cargo Block (FGB) nadir docking port.

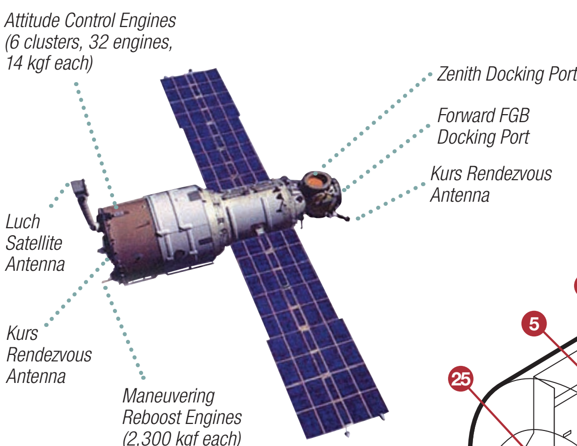
Russian cosmonaut Oleg Skripochka uses the Russian Tekh-38 VETEROK ("Breeze") science hardware to take aero-ionic concentration measurements in the Rassvet Mini-Research Module 1 (MRM1).

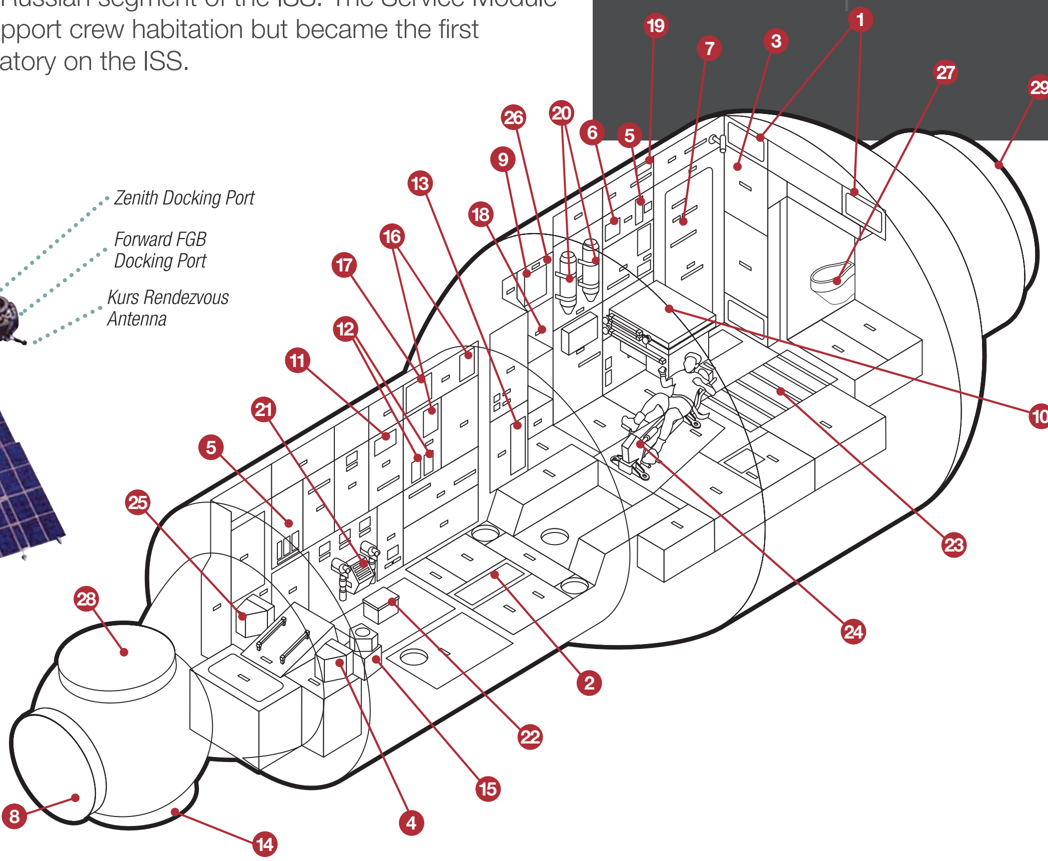
Service Module (SM) Zvezda (Star)

Roscosmos/S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

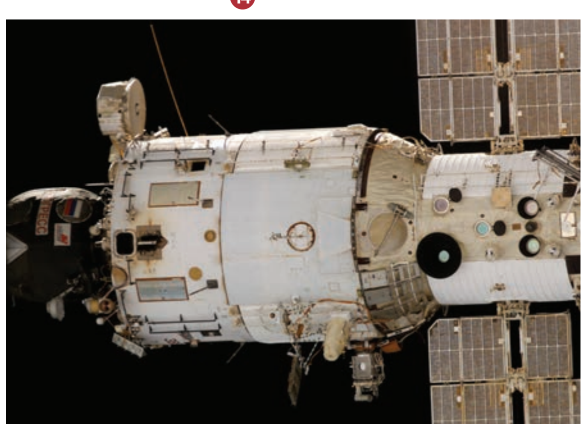
Length	13.1 m (43 ft)
Diameter	4.2 m (13.5 ft)
Wingspan	29.7 m (97.5 ft)
Weight	24,604 kg (54,242 lb)
Launch date	July 12, 2000 Proton 1R
Attitude control	32 engines
Orbital maneuvering	2 engines

The Service Module was the first fully Russian contribution, providing early living quarters, life-support system, electrical power distribution, data processing system, flight control system, and propulsion system. Its communications system still enables remote command capabilities from ground flight controllers. Although some of these systems were subsequently supplemented by U.S. systems, the Service Module remains the structural and functional center of the Russian segment of the ISS. The Service Module was intended primarily to support crew habitation but became the first multipurpose research laboratory on the ISS.





1 Airflow Vent
2 Body Mass Measurement Device
3 Camera
4 Caution and Warning Panel, Clock, and Monitors
5 Communications Panel
6 Condensate Water Processor
7 Crew Sleep Compartment
8 Forward Docking Port (to FGB)
9 Fuses
10 Galley Table
11 Integrated Control Panel
12 Lighting Control Panels
13 Maintenance Box
14 Nadir Docking Port
15 Navigation Sighting Station
16 Night-Lights
17 Power Distribution Panel
18 Recessed Cavity & Valve Panel
19 Smoke Detector
20 Solid Fuel Oxygen Generators (SFOG)
21 Toru Rendezvous Control Station
22 Toru Seat
23 Treadmill & Vibration Isolation System
24 Vela Ergometer
25 Ventilation Screen
26 Vozdukh Control Panel
27 Waste Management Compartment
28 Zenith Docking Port
29 Soyuz and Progress Docking Port



View of the Nadir side of Zvezda Service module.

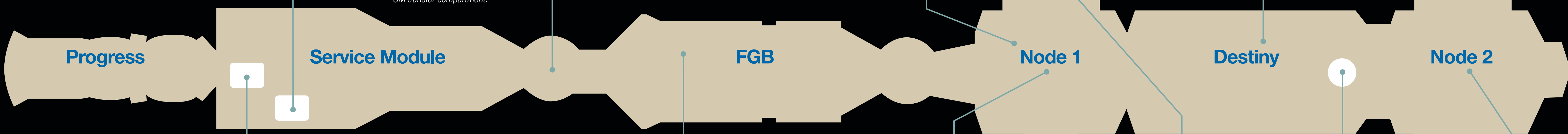
View of Cosmonaut Alexander Samokutyaev during Remote Teleoperator Control Mode Training, in the Service Module (SM).

Habitation

The habitable elements of the ISS are mainly a series of cylindrical modules. Accommodations—including the waste management compartment and toilet, the galley, individual crew sleep compartments, and some of the exercise facilities—are located in the Service Module (SM), Node 1, Node 2, Node 3, and the U.S. Laboratory.

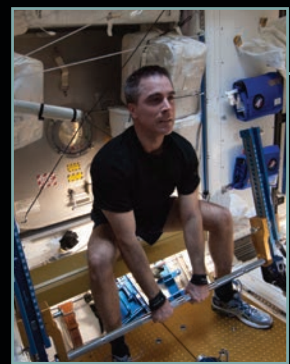
NASA astronaut Sunita Williams vacuuming out crew quarters in the Node 2/Harmony.

Russian cosmonaut Mikhail Tyurin trims the hair of JAXA astronaut Koichi Wakata inside the Unity node.



Russian cosmonaut Alexander Skvortsov pictured in his crew quarters compartment.

SM transfer compartment.



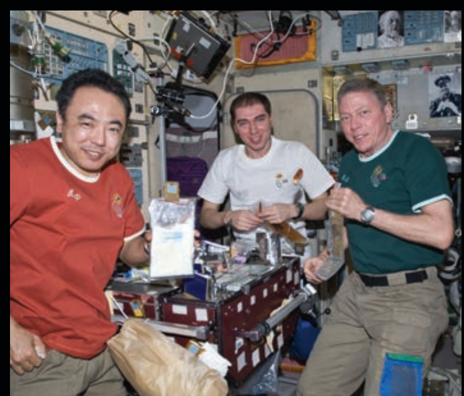
NASA astronaut Chris Cassidy gets a workout on the advanced Resistive Exercise Device (aRED) in Node 3.

Dinner in Node 1 with Russian cosmonaut Oleg Kotov, NASA astronaut Mike Hopkins and JAXA astronaut Koichi Wakata.

ESA astronaut Luca Parmitano exercises on the Combined Operational Load Bearing External Resistance Treadmill (COLBERT).

ESA astronaut Samantha Cristoforetti exercises on the Cycle Ergometer with Vibration Isolation and Stabilization (CEVIS) in the Destiny Laboratory.

Toilet Compartment in the Service Module (SM) / Zvezda.



JAXA astronaut Satoshi Furukaw, NASA astronaut Mike Fossum and Russian cosmonaut Sergei Volkov prepare for a meal in the Service Module galley.

Stowed food trays in FGB.

Interior view of the Node 1 module

NASA Astronauts Rick Mastracchio and Mike Hopkins in the airlock (A/L). Extravehicular Mobility Units (EMUs) are visible.

Waste and Hygiene Compartment (WHC) in the Node 3.

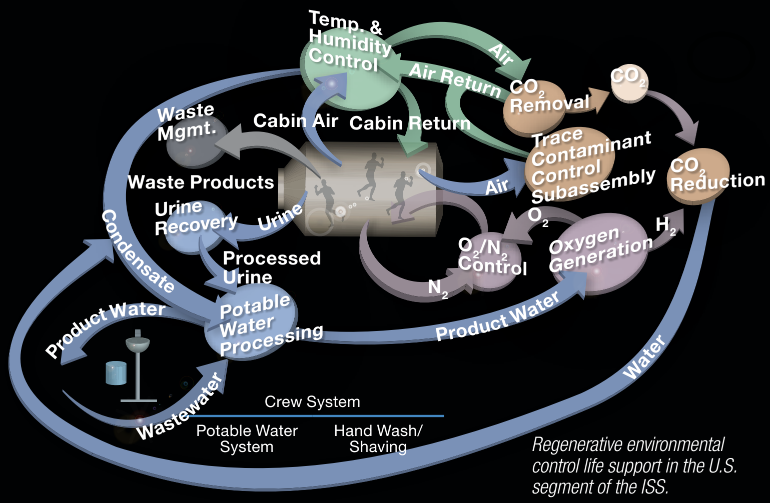
NASA astronaut Susan J. Helms looks out the U.S. Lab Window.

NASA astronaut Karen Nyberg is photographed in her Crew Quarters during her off-duty time.

Environmental Control and Life Support System (ECLSS)

Earth's natural life support system provides the air we breathe, the water we drink, and other conditions that support life. For people to live in space, however, these functions must be performed by artificial means. The ECLSS includes compact and powerful systems that provide the crew with a comfortable environment in which to live and work.

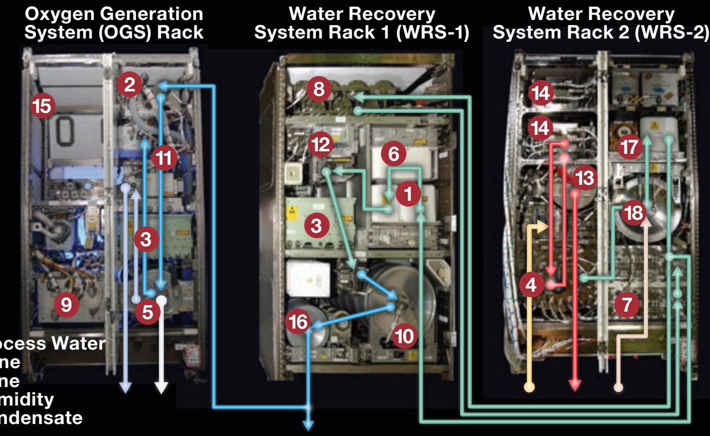
The on-orbit ECLSS is supplemented by an assortment of resupply vehicles provided by the international partnership and U.S. Commercial Resupply System (CRS) vehicles. Water can be resupplied via Iodine Compatible Water Containers (ICWCS) on SpaceX's Dragon, Orbital's Cygnus, or JAXA's H-II Transfer Vehicle (HTV). High pressure oxygen and nitrogen can be resupplied by these same vehicles via the Nitrogen/Oxygen Recharge System (NORS). The Russian Progress also delvers water and atmospheric gas.



Regenerative environmental control life support in the U.S. segment of the ISS.

U.S. Regenerative Environmental Control and Life Support System (ECLSS)

1	Catalytic Reactor	12	Reactor Health Sensor
2	Deionizer Beds	13	Storage Tanks
3	Digital Controller	14	Urine Processor Pumps
4	Distillation Assembly	15	CO_2 Reduction System (Sabatier)
5	Electrolysis Cell Stack	16	Water Processor Delivery Pump
6	Gas Separator	17	Water Processor Pump & Separator
7	Multifiltration Beds	18	Water Processor Wastewater Tank
8	Particulate Filter		
9	Power Supply		
10	Product Water Tank		
11	Pumps & Valves		

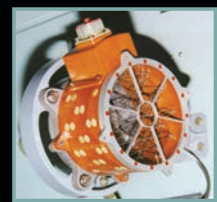


= Oxygen
= Hydrogen (vented overboard)
= Potable Water
= Process Water
= Urine
= Brine
= Humidity Condensate

Elektron produces oxygen from water through electrolysis; vents hydrogen out of the station.

Russian EDVs used to store and transport water.

Vozdukh absorbs carbon dioxide from crew.

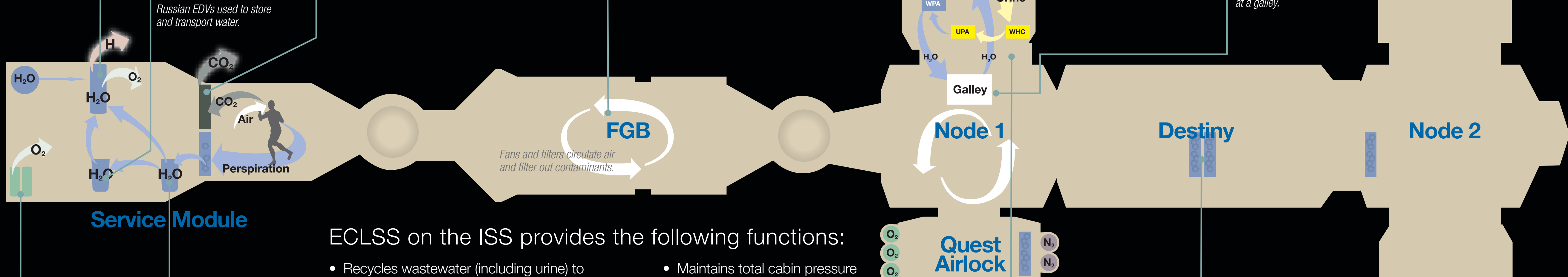


Airflow ventilation fan.

Lithium Hydroxide (LiOH) cartridge used for eliminating CO_2 from air, backup system.

Carbon Dioxide Removal Assembly (CDRA) adsorbs carbon dioxide from crew.

Astronauts share a meal at a galley.



ECLSS on the ISS provides the following functions:

- Recycles wastewater (including urine) to produce drinking (potable) water and technical water (for flush and oxygen generation)
- Stores and distributes potable water
- Uses recycled water to produce oxygen for the crew
- Removes carbon dioxide from the cabin air
- Filters the cabin air for particulates and microorganisms
- Removes volatile organic trace gases from the cabin air
- Monitors and controls cabin air partial pressures of nitrogen, oxygen, carbon dioxide, methane, hydrogen, and water vapor
- Maintains total cabin pressure
- Detects and suppresses fire
- Maintains cabin temperature and humidity levels
- Distributes cabin air between ISS modules (ventilation)

The U.S. Regenerative Environmental Control and Life Support System takes steps toward closing the water cycle; it takes humidity condensate from the cabin air and urine from the crew and converts these into drinking water, oxygen for breathing, and hydrogen which combines with CO_2 scrubbed from the cabin air to make more water.

Solid Fuel Oxygen Generator (SFOG), burns candles to produce oxygen as a backup system.

The Russian Condensate Water Processor is known as the SRV-K, equivalent to the US WPA, processes the condensate that is reclaimed by the SKV.

Waste Hygiene Compartment (WHC) collects urine and waste for processing.

Common Cabin Air Assembly (CCAA) condenses water vapor from air.

Acroymns

WPA Water Processor Assembly
UPA Urine Processor Assembly
OGA Oxygen Generation Assembly.

Crew Health Care System (CHeCS)

The Crew Health Care System (CHeCS) is a suite of hardware on the ISS that provides the medical and environmental monitoring capabilities necessary to ensure the health and safety of crewmembers during long-duration missions. CHeCS is divided into four subsystems:

Countermeasures System (CMS)—The CMS provides the equipment and protocols for the performance of daily exercise to mitigate the deconditioning effects of living in a microgravity environment. The CMS hardware provides aerobic conditioning, interval and resistive training, and also works to preserve aerobic and anaerobic capacity, and muscular strength and endurance.

Environmental Health System (EHS)—The EHS monitors the atmosphere for gaseous contaminants (i.e., from nonmetallic materials off-gassing, combustion products, and propellants), and microbial contamination levels from crewmembers and station activities. The EHS also monitors water quality and acoustics.

Health Maintenance System (HMS)—The HMS provides in-flight life support and resuscitation, medical care to respond to crew illness and injury, preventative health care, and crew health monitoring capabilities.

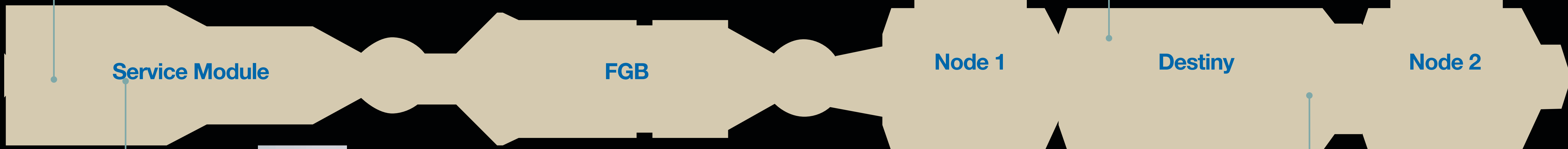
The Radiation System – The Radiation System characterizes the complex, multi-component radiation environment to which the crew is exposed, and records the crewmembers' cumulative exposures. The ionizing radiation environment encountered by ISS consists of a mixture of primary and secondary radiation types:

- Primary radiation varies as a function of ISS altitude and consists mostly of trapped protons, electrons, galactic cosmic radiation and solar flux.
- Secondary radiation products are produced by collisions of primary radiation with the ISS and its hardware inside, as well as inside the crewmembers' bodies.


Russian cosmonaut lena Serova RS 41FE with Microbial Air Sampler (MAS) for the Microbial Sampling investigation.


Russian cosmonaut Roman Romanenko and NASA astronaut Michael Barratt perform a detailed checkout and inspection of the HMS CMRS (Health Maintenance System/Crew Medical Restraint System) in the U.S. Lab. The boardlike CMRS allows strapping down a patient on the board with a harness for medical attention by the CMO who is also provided with restraints around the device.

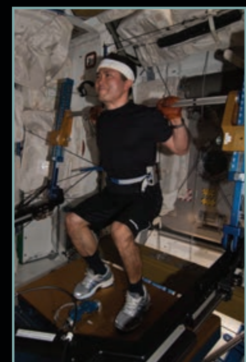

Automated External Defibrillator (AED)

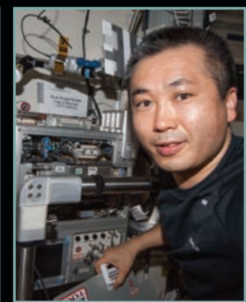



Russian cosmonaut Oleg Kotov exercises on the BD-2 (Begushaya Dorozhka which is a Russian term for a treadmill).


ESA astronaut Frank De Winne taking water samples.


NASA astronaut Reid Wiseman exercises on the Combined Operational Load Bearing External Resistance Treadmill (COLBERT).


JAXA astronaut Koichi Wakata exercises on the ARED.


JAXA astronaut Koichi Wakata with TOCA for water sampling session.


NASA astronaut Mike Fincke uses Cycle Ergometer with Vibration Isolation System (CEVIS).


ESA astronaut Luca Parmitano with Colorimetric Water Quality Monitoring Kit (CWQMK).

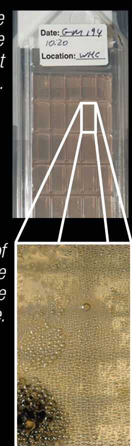

Radiation Area Monitor (RAM)(Dosimeter).


ESA astronaut Andre Kuipers with Acoustic Dosimeter.


NASA astronaut Bill Shepherd exercises on the Velo Ergometer Bike.


IV- Tissue Equivalent Proportional Counter (IV-TEPC).


NASA astronaut Steve Swanson with Sound Level Meter (SLM) to take noise level measurements.


SSK sample in the Waste Hygiene Compartment (WHC).

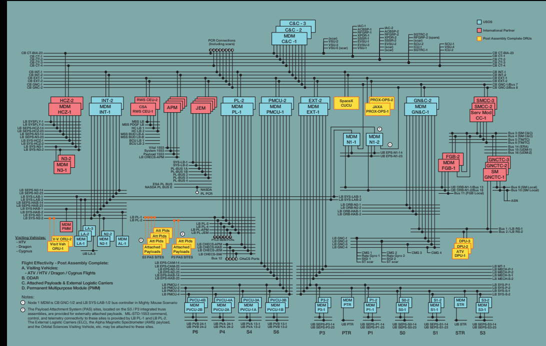
Close-up view of a Surface Sample Kit (SSK) surface slide.


Canadian astronaut Robert Thirsk uses the Surface Sample Kit (SSK) to collect and incubate microbiology samples.


NASA astronaut Karen Nyberg performs an Ocular Health (OH) Fundoscope Exam.

Computers and Data Management

The system for storing and transferring information essential to operating the ISS has been functioning at all stages of assembly and provides control from various segments of the ISS. The Enhanced Processor and Integrated Communications upgrade in some of the Multiplexer/Demultiplexers (MDMs) has vastly improved the processing and memory margins; in addition to adding a new Ethernet interface. The Portable Computer System laptops provide the crew interface for commanding and monitoring the ISS Core Systems hardware and associated software.

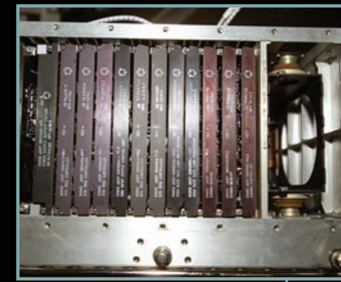


Data bus architecture consists of

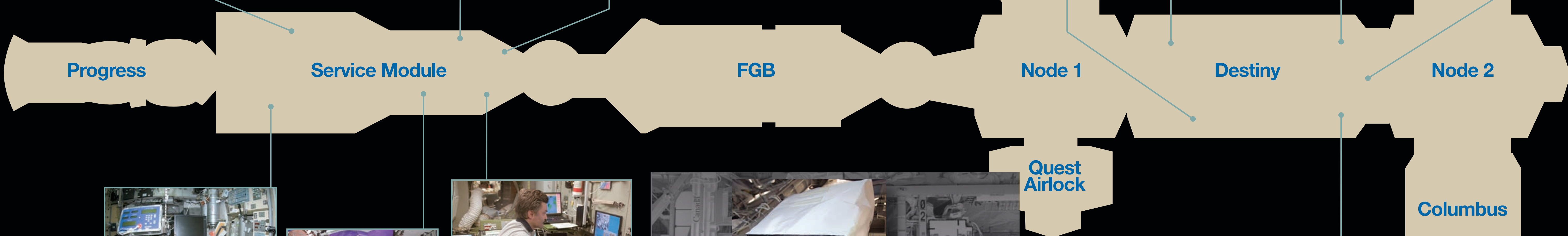
- 105+ MIL-STD-1553 Data buses
- 60+ computers (48 MDMs) into which software can be as necessary
- 650+ RTs plus IP RTs on buses
- 190 payload remote terminals (RTs)
- 600+ International partners (IPs) and firmware controller devices
- 90 Unique types of remote devices

Maneuvering Truss Segments into Place at SSRMS Workstation.

SSRMS Control and Robotics Workstations.



Multiplexer/Demultiplexer with Solid State Mass Memory Unit (SSMMU) and Processor cards in US lab.



Laptop (in SM crew quarters).

Primary Command Workstation in SM.

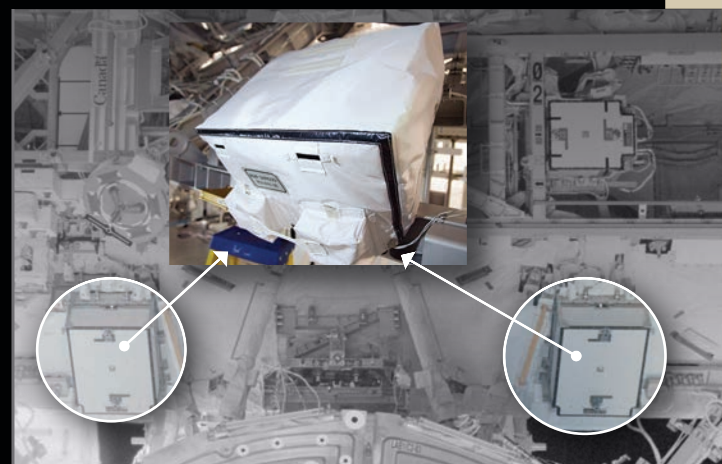
Crew uses Progress Remote Control workstation in SM.

Multiplexer/Demultiplexer (computer).

Laptop and TVIS Control (located near galley).

Russian Segment Workstations.

TORU Remote Progress Docking Workstation.



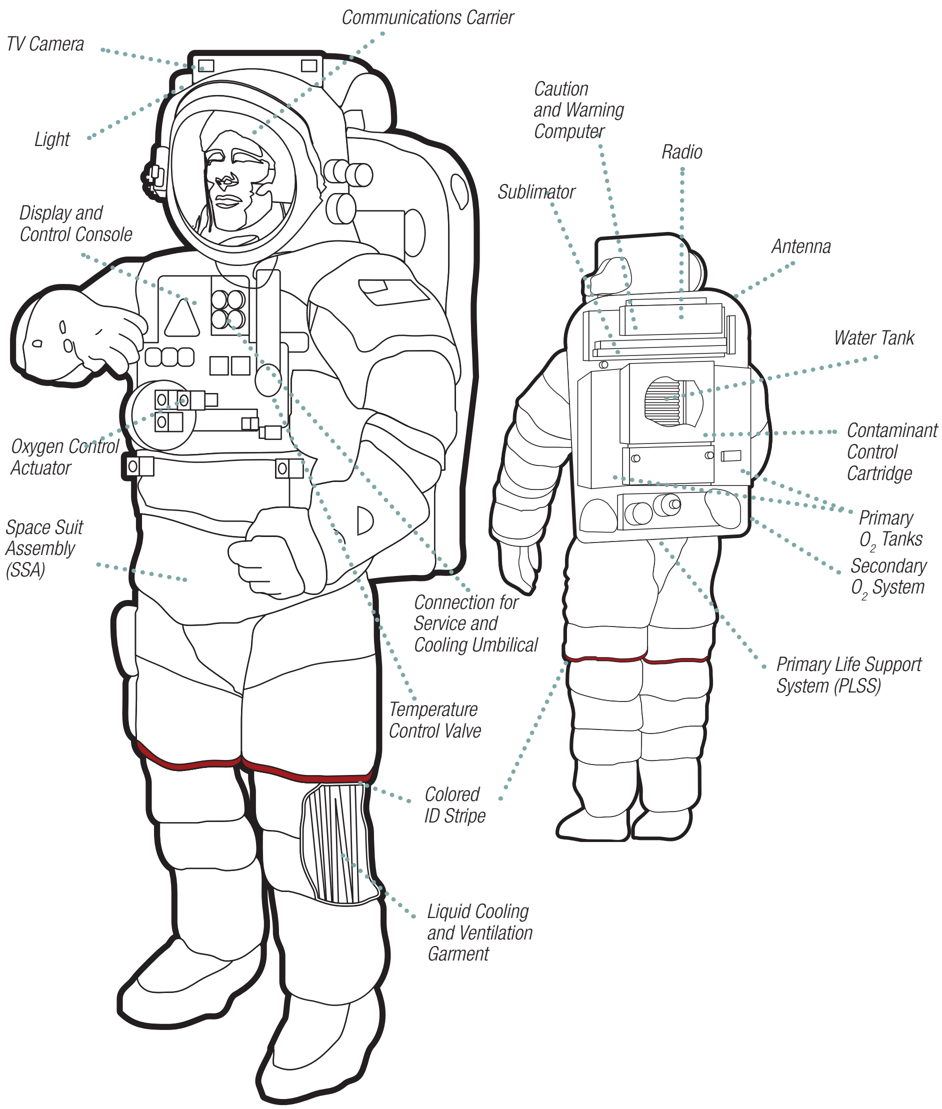
Multiplexer/Demultiplexers (mounted externally on the truss).

Human Research Facility Workstation.

Extravehicular Mobility Unit (EMU)

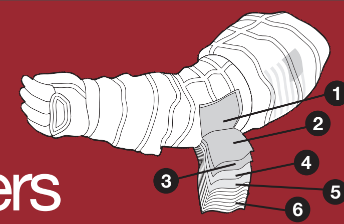
NASA/Hamilton Sundstrand/ILC Dover

The EMU provides a crewmember with life support and an enclosure that enables an EVA (Extravehicular Activity). The unit consists of two major subsystems: the Primary Life Support Subsystem (PLSS) and the Space Suit Assembly (SSA). The EMU provides atmospheric containment, thermal insulation, cooling, solar radiation protection, and micrometeoroid/orbital debris (MMOD) protection.



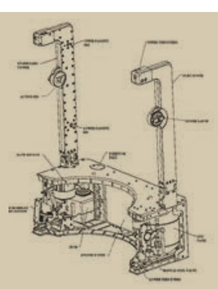
Suit's nominal pressure	0.3 atm (4.3 psi)
Atmosphere	100% oxygen
Primary oxygen tank pressure	900 psi
Secondary oxygen tank pressure	6,000 psi (30-min backup supply)
Maximum EVA duration	8 h
Mass of entire EMU	143 kg (315 lb)
Suit life	25 EVA's or 6 years prior to returning to Earth

Suit Layers



1. Thermal Micrometeoroid Garment (TMG). Cover: Ortho/KEVLAR® reinforced with GORE-TEX®.
2. TMG Insulation. Five to seven layers of aluminized Mylar® (more layers on arms and legs).
3. TMG liner. Neoprene-coated nylon ripstop.
4. Pressure garment cover. Restraint: Dacron®.
5. Pressure garment bladder. Urethane-coated nylon oxford fabric.
6. Liquid cooling garment. Neoprene tubing.

The Simplified Aid For EVA Rescue (SAFER) provides a compressed nitrogen-powered backpack that permits a crewmember to maneuver independently of the ISS. Its principal use is that it allows a crewmember to maneuver back to the station if he or she becomes detached from the ISS.



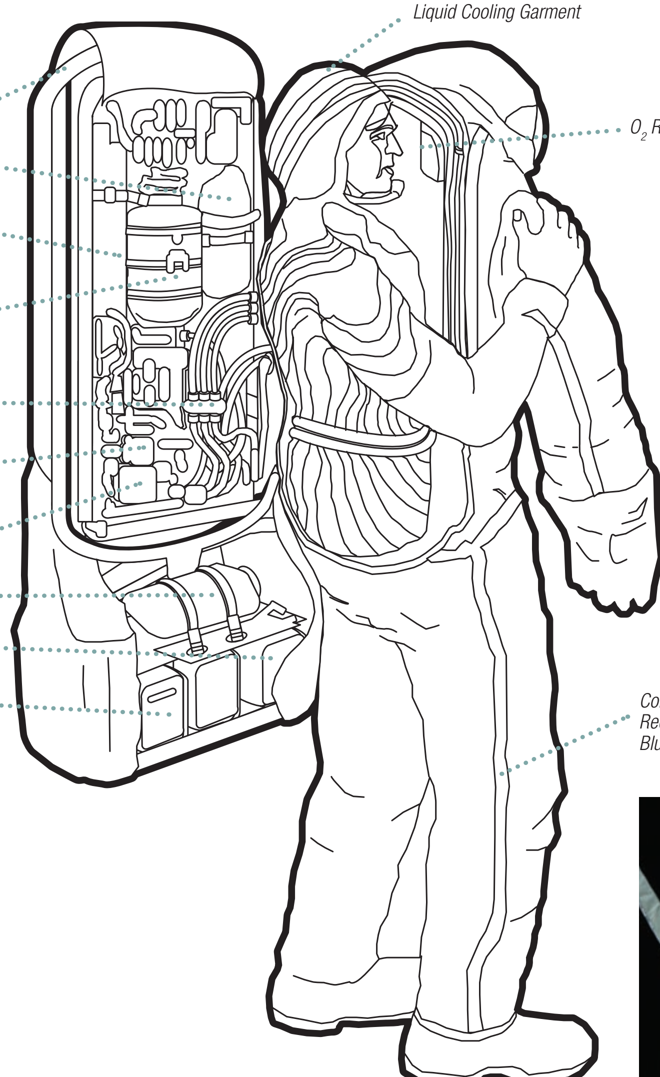
NASA astronaut Chris Cassidy participates in a session of extravehicular activity (EVA). During the six-hour, seven-minute spacewalk, Cassidy was preparing the space station for a new Russian module and performed additional installations on the station's backbone.

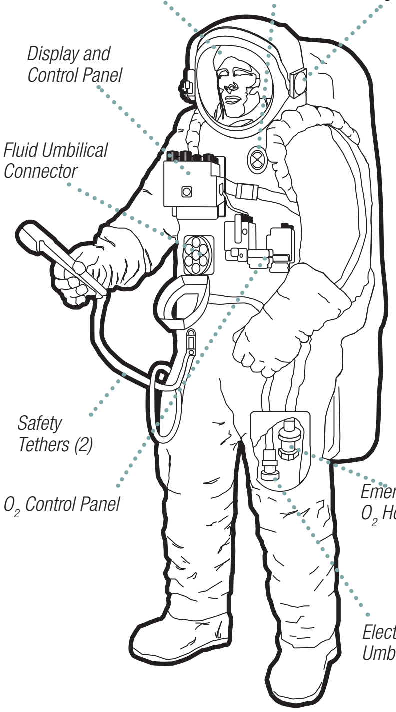
Orlan Spacesuit

Russian Federal Space Agency (Roscosmos)/ Science Production Enterprise Zvezda

Suit's nominal pressure	0.4 atm (5.8 psi)
Atmosphere	100% oxygen
Maximum EVA duration	7 h
Mass of entire EMU	108 kg (238 lb)
Suit life	15 EVAs or 4 years without return to Earth

The Orlan-MK spacesuit is designed to protect an EVA (Extravehicular Activity) crewmember from the vacuum of space, ionizing radiation, solar energy, and micrometeoroids. The main body and helmet of the suit are integrated and are constructed of aluminum alloy. Arms and legs are made of a flexible fabric material. Crewmembers enter from the rear via the backpack door, which allows rapid entry and exit without assistance. The Orlan-MK spacesuit is a "one-size-fits-most" suit.





Russian cosmonaut Alexander Misurkin, attired in a Russian Orlan spacesuit (blue stripes),participates in a session of extravehicular activity (EVA) to continue outfitting the International Space Station.

Mobile Servicing System (MSS)

Space Station Remote Manipulator System (SSRMS/ Canadarm2)
Special Purpose Dexterous Manipulator (SPDM/Dextre)
Mobile Base System (MBS)
Canadian Space Agency (CSA)

	SSRMS	MBS	SPDM
Length/ height	17.6 m (57 ft)		3.5 m (11.4 ft)
Maximum diameter	.36 m (1.2 ft)		.88 m (2.9 ft)
Dimensions		5.7 × 4.5 × 2.9 m (18.5 × 14.6 × 9.4 ft)	
Mass	1,497 kg (3,300 lb)	1,450 kg (3,196 lb)	1,662 kg (3,664 lb)
Degrees of freedom	7		

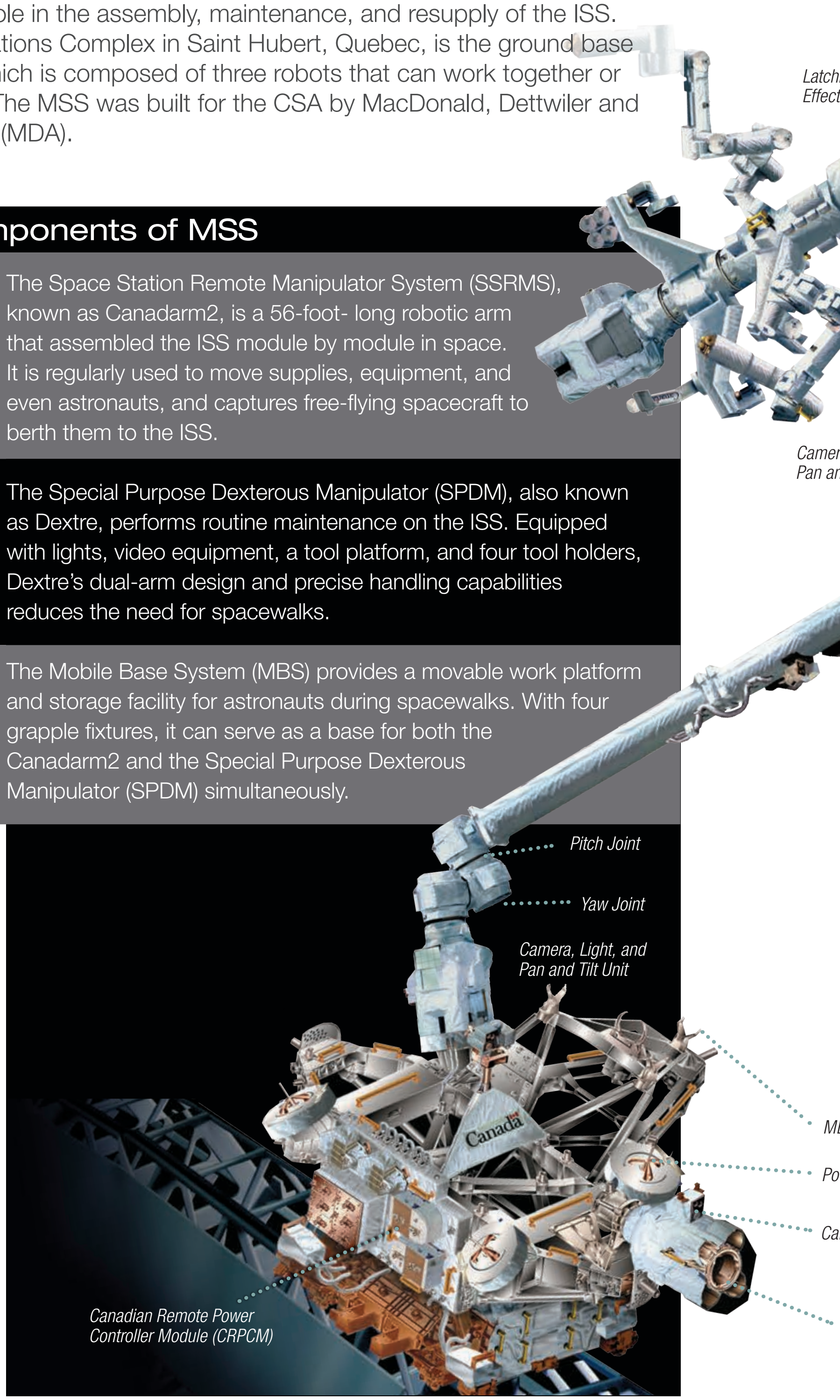
The Mobile Servicing System (MSS) is a sophisticated robotics suite that plays a critical role in the assembly, maintenance, and resupply of the ISS. The MSS Operations Complex in Saint Hubert, Quebec, is the ground base for the MSS, which is composed of three robots that can work together or independently. The MSS was built for the CSA by MacDonald, Dettwiler and Associates Ltd. (MDA).

Three components of MSS

The Space Station Remote Manipulator System (SSRMS), known as Canadarm2, is a 56-foot- long robotic arm that assembled the ISS module by module in space. It is regularly used to move supplies, equipment, and even astronauts, and captures free-flying spacecraft to berth them to the ISS.

The Special Purpose Dexterous Manipulator (SPDM), also known as Dextre, performs routine maintenance on the ISS. Equipped with lights, video equipment, a tool platform, and four tool holders, Dextre's dual-arm design and precise handling capabilities reduces the need for spacewalks.

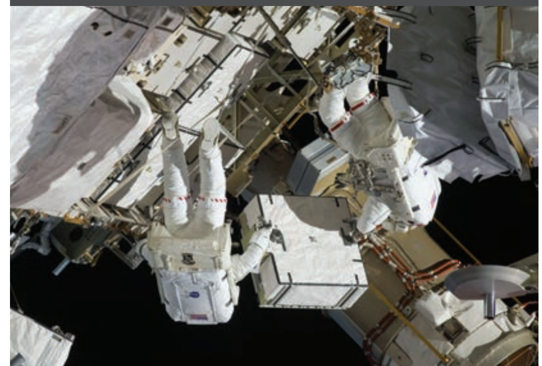
The Mobile Base System (MBS) provides a movable work platform and storage facility for astronauts during spacewalks. With four grapple fixtures, it can serve as a base for both the Canadarm2 and the Special Purpose Dexterous Manipulator (SPDM) simultaneously.



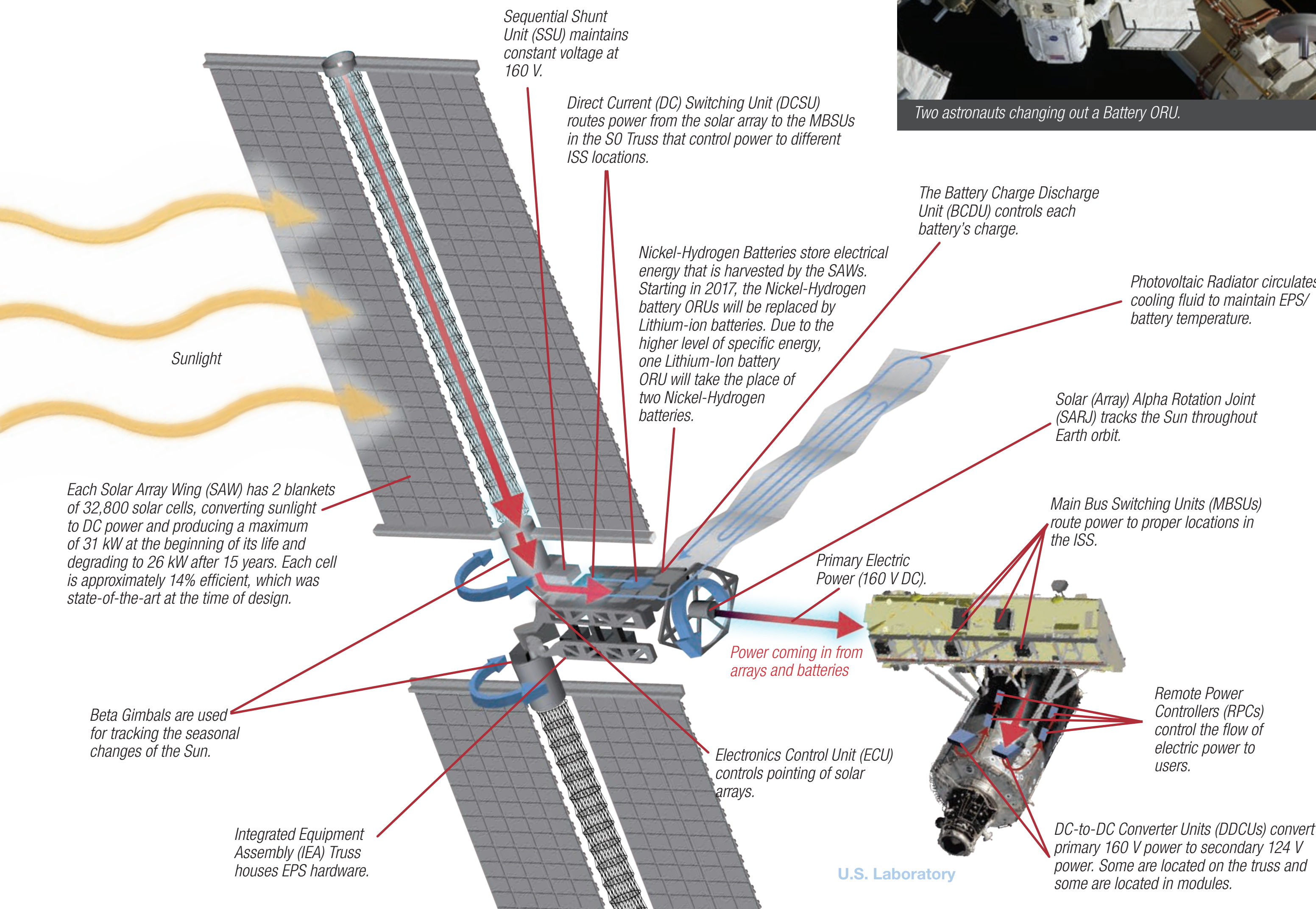
Backdropped by Earth's horizon and the blackness of space, the Canadian-built Dextre, also known as the Special Purpose Dextrous Manipulator (SPDM), is featured in this image.

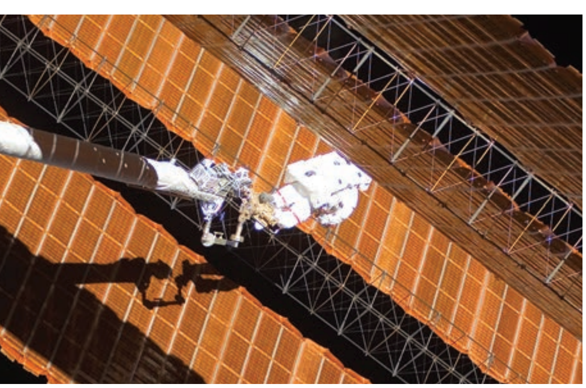
Electrical Power System (EPS)

The EPS generates, stores, and distributes power and converts and distributes secondary power to users.



Two astronauts changing out a Battery ORU.





NASA astronaut Scott Parazynski, anchored to the Articulating Portable Foot Restraint (APFR) on the Orbiter Boom Sensor System (OBSS), assesses repair work on the P6 4B Solar Array Wing (SAW) as the array is deployed during an extravehicular activity (EVA).

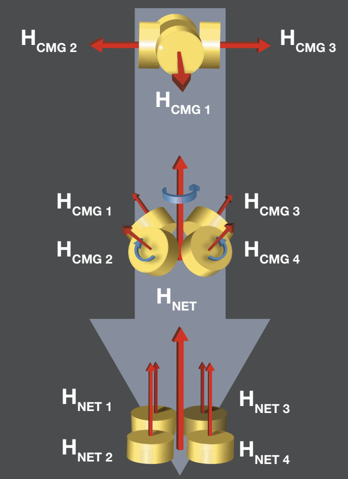
Guidance, Navigation, and Control (GN&C)

The ISS is a large, free-flying vehicle. The attitude or orientation of the ISS with respect to Earth and the Sun must be controlled; this is important for maintaining thermal, power, and microgravity levels, as well as for communications.

The ISS GN&C hardware consists of GPS receivers and antennas, rate gyro sensors, control moment gyros on the U.S. segment, and thrusters, star trackers, GPS receivers, and rate gyros on the Russian segment. The GPS receivers provide information about the location of the ISS, and the rate gyros provide information about the change in orientation of the ISS. Both U.S. and Russian segment GN&C systems have extensive software to be able to determine and control the ISS orientation. The GN&C system tracks the Sun, communications and navigation satellites, and ground stations. Solar arrays, thermal radiators, and communications antennas aboard the ISS are pointed using information from the GN&C system.

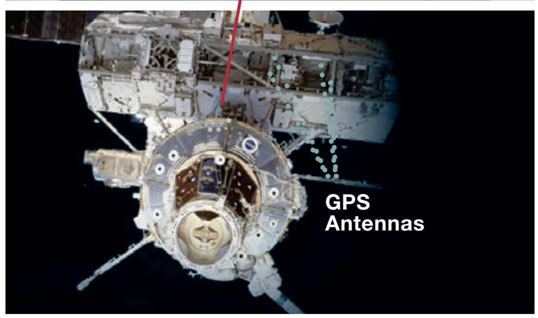
The preferred method of attitude control is the use of Control Moment Gyroscopes (CMGs), sometimes called gyrodynes in other programs, mounted on the Z1 Truss segment. Each CMG has 98-kilogram (220-pound) flywheel that spins at 6,600 revolutions per minute (rpm). The high-rotational velocity and large mass of the flywheel allow a considerable amount of angular momentum to be stored. Each CMG has gimbals such that the flywheels can be repositioned. As the flywheel is repositioned, the resulting force orients the ISS. Using multiple CMGs permits the ISS to be moved to new attitudes or permits the attitude to be held constant. The advantages of this system are that it relies on electrical power generated by the solar arrays and that it provides smooth, continuously variable attitude control. CMGs are; however, limited in the amount of angular momentum they can provide and the rate at which they can move the station. When CMGs can no longer provide the requisite energy, Russian segment thrusters are used.

Control Moment Gyroscope gimbals used for orienting the ISS.

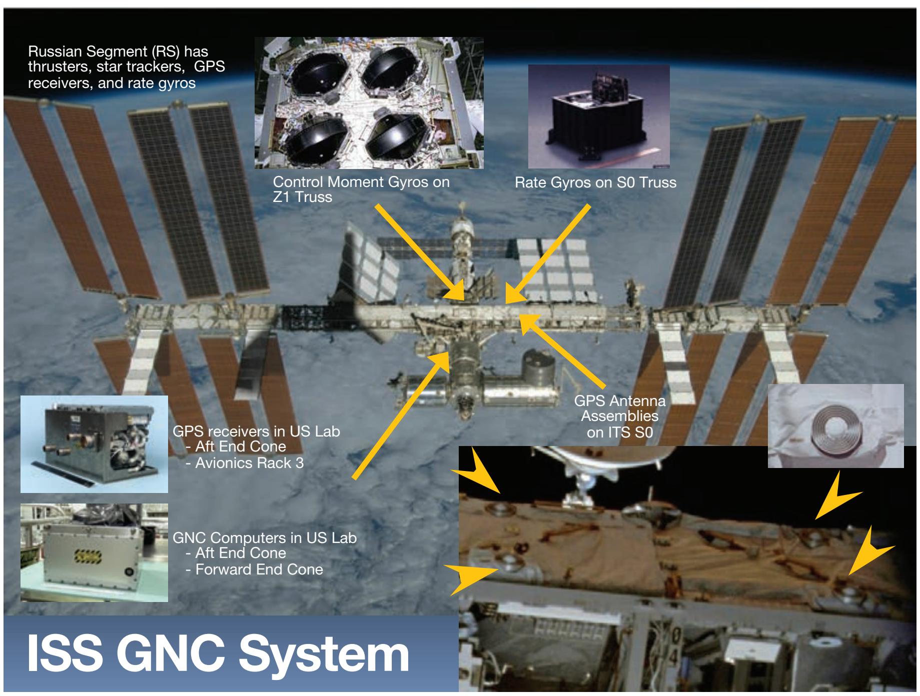


Forces are induced as CMGs are repositioned.

GPS antenna on S0 Truss.

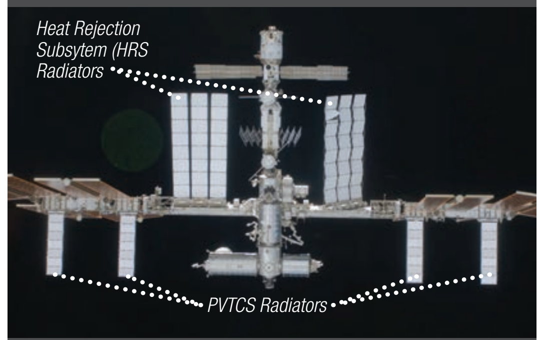


GPS Antennas



ISS GNC System

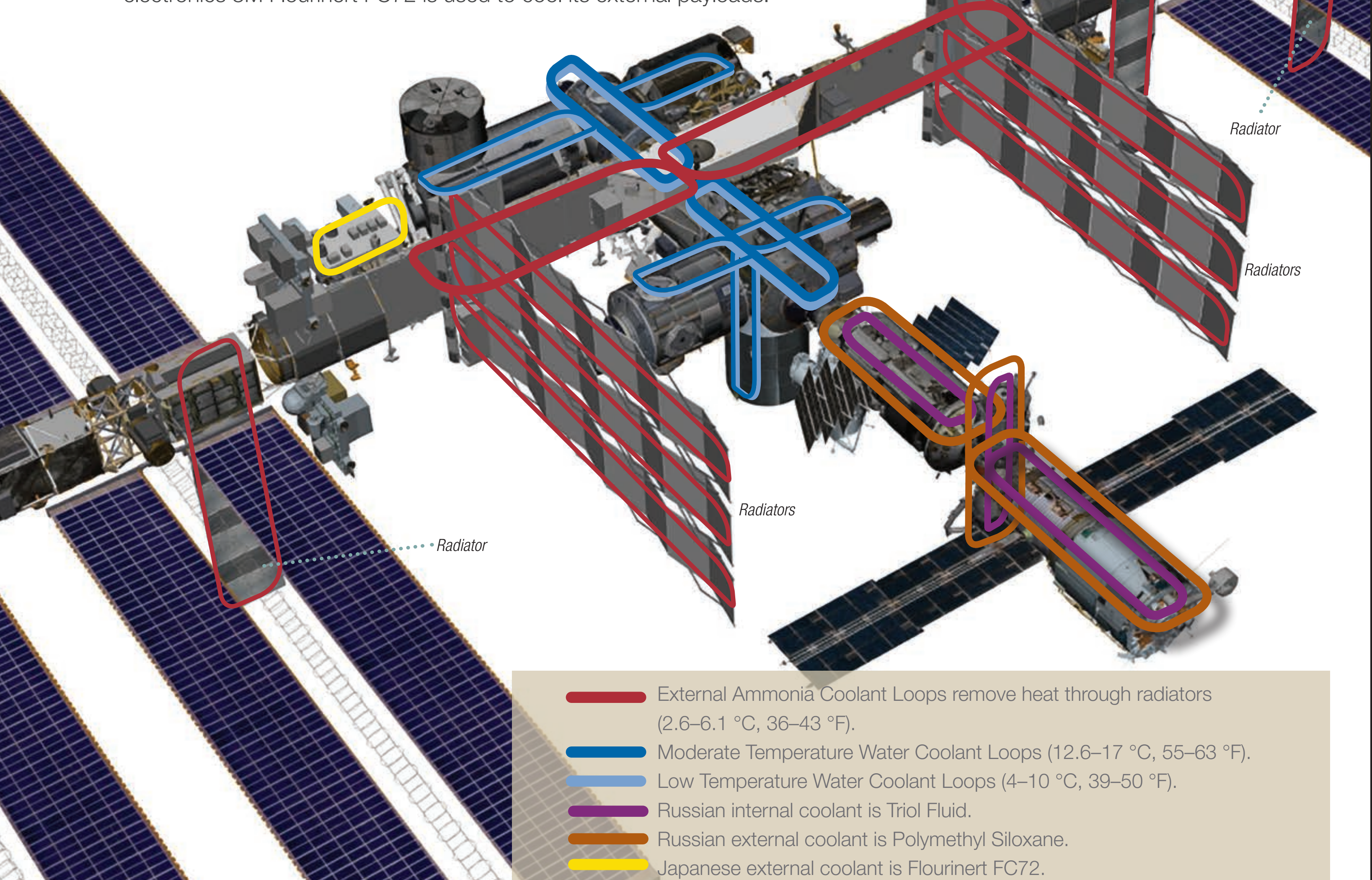
Thermal Control System (TCS)



International Space Station with all radiators deployed.

The TCS maintains ISS temperatures within defined limits. The four components used in the Passive Thermal Control System (PTCS) are insulation, surface coatings, heaters, and heat pipes.

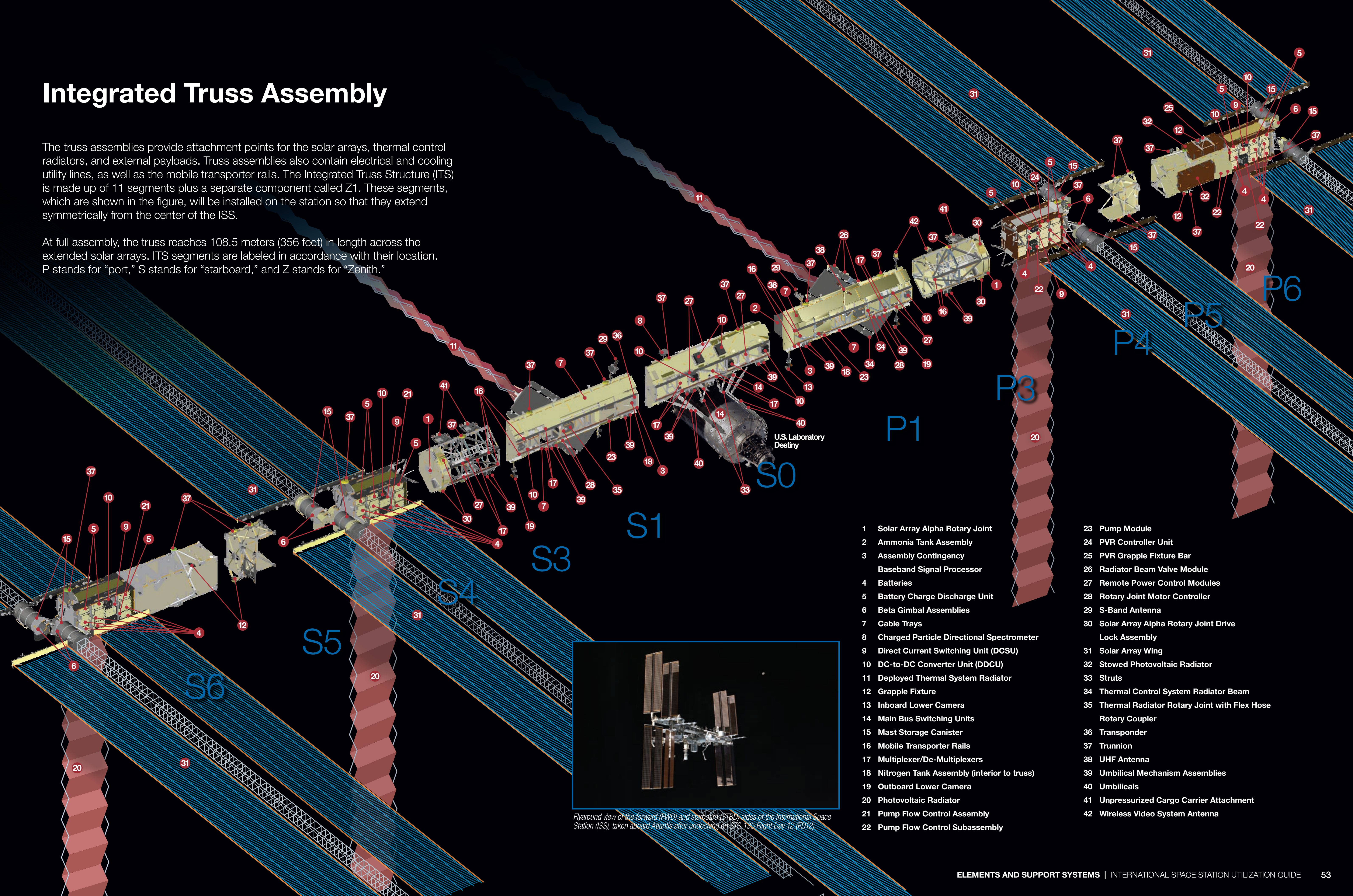
The Active Thermal Control System services point source heat loads such as electrical equipment on cold plates as well as providing heat rejection for the crew cabin using pumps to move heat rejection fluids through the vehicle. The water-based internal cooling loops are used in controlling humidity and removing heat loads generated by the crew and electronic equipment. This heat is transferred to interface heat exchangers located on the exterior of the vehicle. The interface heat exchangers flow water on one side, and transfer the heat to anhydrous ammonia flowing on the other side. The warmed ammonia rejects heat to space from the six large Heat Rejection Subsystem (HRS) radiators. There is a single independent PhotoVoltaic Thermal Control System (PVTCS) radiator for each of the four pairs of solar array wings that use pumps and anhydrous ammonia to reject heat from the power generating equipment. In the Japanese Exposed Facility (JEF) a fluid commonly used in electronics 3M Flourinert FC72 is used to cool its external payloads.



Integrated Truss Assembly

The truss assemblies provide attachment points for the solar arrays, thermal control radiators, and external payloads. Truss assemblies also contain electrical and cooling utility lines, as well as the mobile transporter rails. The Integrated Truss Structure (ITS) is made up of 11 segments plus a separate component called Z1. These segments, which are shown in the figure, will be installed on the station so that they extend symmetrically from the center of the ISS.

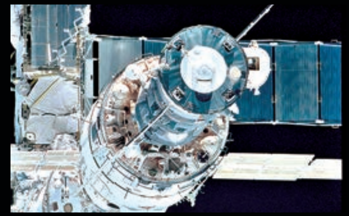
At full assembly, the truss reaches 108.5 meters (356 feet) in length across the extended solar arrays. ITS segments are labeled in accordance with their location. P stands for “port,” S stands for “starboard,” and Z stands for “Zenith.”

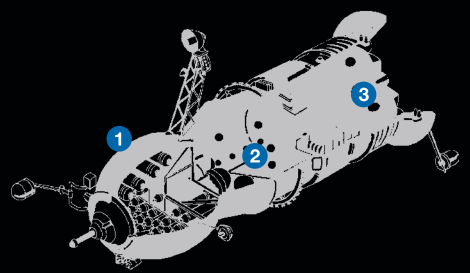


1 Solar Array Alpha Rotary Joint
2 Ammonia Tank Assembly
3 Assembly Contingency Baseband Signal Processor
4 Batteries
5 Battery Charge Discharge Unit
6 Beta Gimbal Assemblies
7 Cable Trays
8 Charged Particle Directional Spectrometer
9 Direct Current Switching Unit (DCSU)
10 DC-to-DC Converter Unit (DDCU)
11 Deployed Thermal System Radiator
12 Grapple Fixture
13 Inboard Lower Camera
14 Main Bus Switching Units
15 Mast Storage Canister
16 Mobile Transporter Rails
17 Multiplexer/De-Multiplexers
18 Nitrogen Tank Assembly (interior to truss)
19 Outboard Lower Camera
20 Photovoltaic Radiator
21 Pump Flow Control Assembly
22 Pump Flow Control Subassembly
23 Pump Module
24 PVR Controller Unit
25 PVR Grapple Fixture Bar
26 Radiator Beam Valve Module
27 Remote Power Control Modules
28 Rotary Joint Motor Controller
29 S-Band Antenna
30 Solar Array Alpha Rotary Joint Drive Lock Assembly
31 Solar Array Wing
32 Stowed Photovoltaic Radiator
33 Struts
34 Thermal Control System Radiator Beam
35 Thermal Radiator Rotary Joint with Flex Hose Rotary Coupler
36 Transponder
37 Trunnion
38 UHF Antenna
39 Umbilical Mechanism Assemblies
40 Umbilicals
41 Unpressurized Cargo Carrier Attachment
42 Wireless Video System Antenna

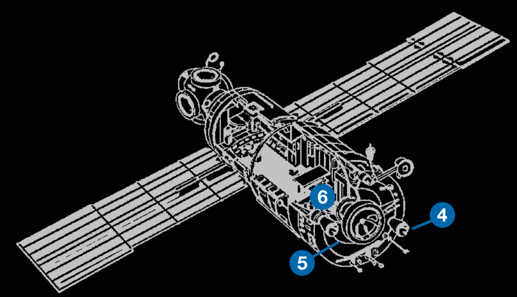
Flyaround view of the forward (FWD) and starboard (STBD) sides of the International Space Station (ISS), taken aboard Atlantis after undocking on STS-135 Flight Day 12 (FD12).

Propulsion

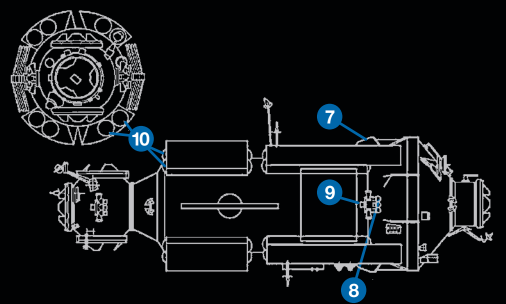




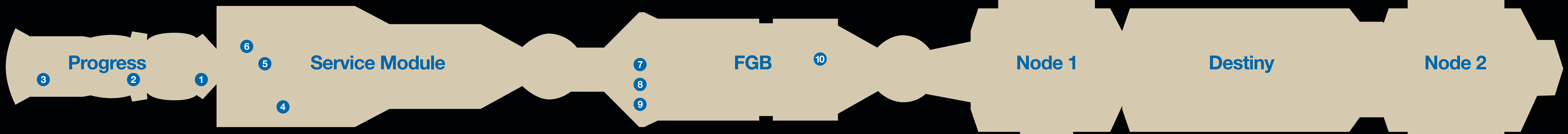
1. Progress Cargo Module
2. Propellant Resupply Tanks
3. Progress Propulsion System



4. Main Engines (2)
5. Attitude Control Engines (32)
6. Propellant Tanks (4)



7. Correction and Docking Engines (2)
8. Correction and Docking Engines (2)
9. Accurate Stabilization Engines (16)
10. Propellant Tanks (16)



Progress Rocket Engines

Progress is used for propellant resupply and for performing reboosts. For the latter, Progress is preferred over the Service Module. Progress uses four or eight attitude control engines, all firing in the direction for reboost.

Orbital Correction Engine:
1 axis, 300 kgf (661 lbf)

Attitude Control Engines:
28 multidirectional, 13.3 kgf (29.3 lbf)

Service Module Rocket Engines

Main Engines: 2,300 kgf (661 lbf); one or both main engines can be fired at a time; they are fed from the Service Module's propellant storage system

Attitude Control Engines: 32 multidirectional, 13.3 kgf (29.3 lbf); attitude control engines can accept propellant fed from the Service Module, the attached Progress, or the FGB propellant tanks

Service Module Propellant Storage
Two pairs of 200-L (52.8-gal) propellant tanks (two nitrogen tetroxide N_2O_4 and two unsymmetrical dimethyl hydrazine [UDMH]) provide a total of 860 kg (1,896 lb) of usable propellant. The propulsion system rocket engines use the hypergolic reaction of UDMH and N_2O_4. The Module employs a pressurization system using N_2 to manage the flow of propellants to the engines.

FGB Rocket Engines

FGB engines are deactivated once the Service Module is in use.

Correction and Docking Engines:
2 axis, 417 kgf (919 lbf)

Docking and Stabilization Engines:
24 multidirectional, 40 kgf (88 lbf)

Accurate Stabilization Engines:
16 multidirectional, 1.3 kgf (2.86 lbf)

FGB Propellant Storage

There are two types of propellant tanks in the Russian propulsion system: bellows tanks (SM, FGB), able both to receive and to deliver propellant, and diaphragm tanks (Progress), able only to deliver fuel.

Sixteen tanks provide 5,760 kg (12,698 lb) of N_2O_4 and UDMH storage: eight long tanks, each holding 400 L (105.6 gal), and eight short tanks, each holding 330 L (87.17 gal).

The ISS orbits Earth at an altitude ranging from 370 to 460 kilometers (230 to 286 miles) and at a speed of 28,000 kilometers per hour (17,500 miles per hour). Due to atmospheric drag, the ISS is constantly slowed and must be re-boosted periodically to maintain its altitude. The ISS must be maneuvered to assist in rendezvous and docking of visiting vehicles and to avoid debris.

Thrusters located on the Service Module, as well as on the docked vehicles are used to perform these maneuvers.

The Service Module provides thirty-two 13.3-kilograms force (29.3-pounds force) attitude control engines. The engines are combined into two groups of 16 engines each, taking care of pitch, yaw, and roll control. Each Progress provides 24 engines similar to those on the Service Module. When a Progress is docked at the aft Service Module port, these engines can be used for pitch and yaw control. When the Progress is docked at the Russian Docking Module, the Progress engines can be used for roll control.

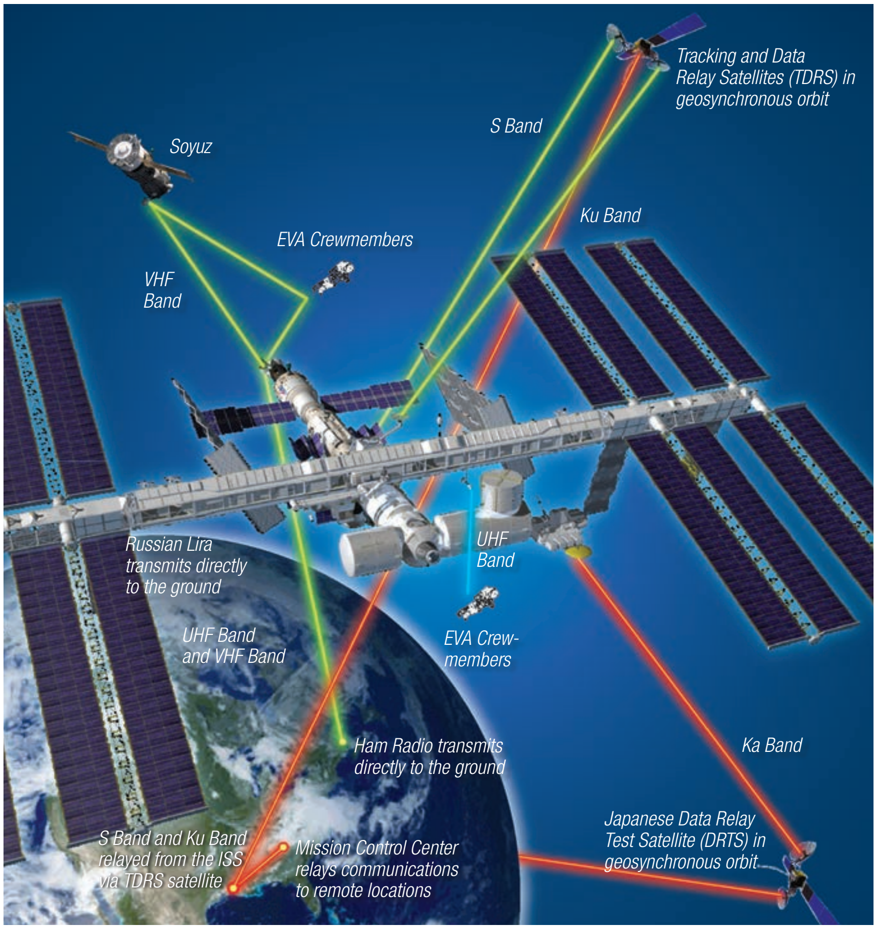
Besides being a resupply vehicle, the Progress provides a primary method for reboosting the ISS. Eight 13.3-kilograms force (29.3-pounds force) Progress engines can be used for reboosting. The Service Module engines can also be used for reboosting. The Progress can also be used to resupply propellants stored in the FGB that are used in the Service Module engines.

Communications

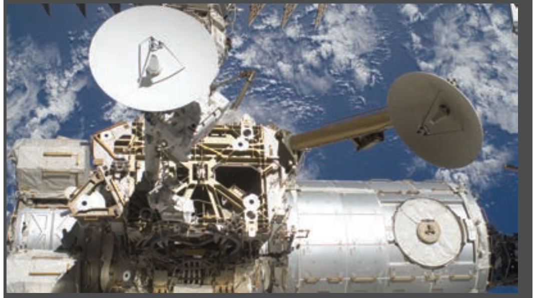
The Communications & Tracking (C&T) System provides Radio Frequency (RF) links between ISS and the Mission Control Center-Houston (MCC-H), other ground control centers, and Payload Operations Centers (POCs) around the world via the Tracking & Data Relay Satellite System provided by NASA's Space Network. These links support all ISS mission operations via real-time exchange of digital audio, video, and systems and payload data. It also enables the flight control team and POCs on the ground to control, operate and monitor performance of ISS systems and payloads.

The C&T System provides the following:

- Two-way audio between crew aboard the ISS and with Control Centers, including exchange of audio and receipt of video from Extravehicular Activity (EVA) crew.
- Downlink of high-rate payload science data to MCC-H and the Payload Operations & Integration Center (POIC) for distribution to payload scientists.
- Two-way crew support (email, daily planning products, family & medical teleconferencing, IP Phone, public affairs broadcasts).
- Transmission of multiple video channels to the ground.
- Communications with Visiting Vehicles including the new Common Communications for Visiting Vehicles (C2V2) system currently in development for use by future Commercial Crew and Commercial Cargo/ Resupply vehicles.

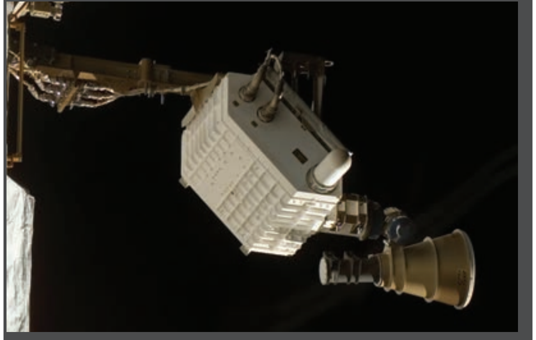


Ku band radio in U.S. Lab.



Ku band radio on exterior of ISS.

UHF antenna on the P1 Truss.



S-band Antenna Support Assembly

Crewmembers performing a public affairs event in Kibo.

Micrometeoroid and Orbital Debris (MMOD) Protection

Spacecraft in low-Earth orbit are continually impacted by meteoroids and orbital debris. Most of the meteoroids and debris are small and cause little damage. A small fraction of the meteoroid and debris populations, however, are larger and can cause severe damage in a collision with a spacecraft.

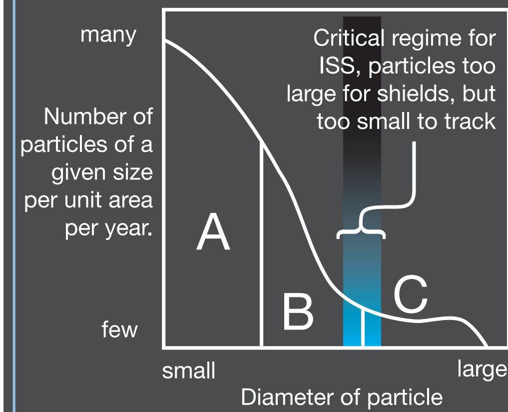
The International Space Station (ISS) is the largest spacecraft ever built. With the completion of assembly more than 11,000m^2 (118,400 ft^2) of surface area is exposed to the space environment. Due to its large surface area, its long planned lifetime, and the potential for a catastrophic outcome of a collision, protecting the ISS from meteoroids and debris poses a unique challenge.

Many ISS elements are shielded from impacts. The primary shielding configurations are:

- Whipple shield is a two layer shield consisting of an outer bumper, usually aluminum, spaced some distance from the module pressure shell wall; the bumper plate is intended to break up, melt, or vaporize a particle on impact. This type of shield is used where few MMOD impacts are expected (aft, nadir and zenith areas of ISS.)

- Stuffed Whipple shield consists of an outer bumper, an underlying blanket of Nextel ceramic cloth, and Kevlar fabric to further disrupt and disperse the impactor spaced a distance from the module pressure shell. Because these shields have a higher capability than Whipple shields, they are used where more MMOD impacts are expected to occur (front and starboard/port sides of ISS).

Windows are generally multi-pane with separate and redundant pressure panes, as well as an outer debris pane and/or shutter to provide protection from MMOD. Other critical areas, such as electrical, data, and fluid lines on the truss and radiator panels, are toughened with additional protective layers to prevent loss from MMOD impacts.

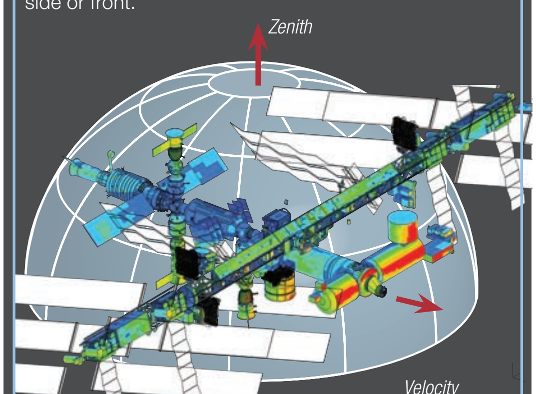


A. Pressure shell penetrations unlikely
B. Possible penetrations that can be mitigated with shields
C. Larger debris is tracked and ISS is maneuvered out of impact path

A 5 inch long by 4 inch wide hole found in 2014 in a port-side radiator for the solar array power system. No coolant leak occurred due to this impact damage.

Threat Directions

Micrometeoroids may approach the ISS from any direction but are less likely from below, where earth acts as a shield. debris will typically approach ISS on a path roughly parallel with earth's surface and from the side or front.



Exterior view of the Cupola Module and JAXA astronaut Koichi Wakata inside, looking out through one of the windows.

U.S. Lab in orbit, above, NASA astronaut Ken Bowersox uses camera at window with partially deployed shutter; to right, window shutter fully deployed; outer debris shields are visible.

International Partnership

Launched in 1998 and involving the U.S., Russia, Canada, Japan, and the participating countries of the European Space Agency—the International Space Station is the most ambitious international collaborations ever attempted. It has been visited by astronauts from 14 countries.

Operating the space station is even more complicated than other space flight endeavors because it is an international program. The station requires the support of facilities on the Earth managed by all of the international partner agencies, countries and commercial entities involved in the program.

Active ISS Operations and Management


ESA European Space Research and Technology Center (ESTEC)
Noordwijk, Netherlands
ISS Mission Control
Korolev, Russia
Roscosmos Headquarters
Moscow, Russia
Kibo HTV Control Center and Crew Training
Tsukuba, Japan
Russian Launch Control Baikonur Cosmodrome
Baikonur, Kazakhstan
Columbus Control Center
Oberpfaffenhofen, Germany
Gagarin Cosmonaut Training Center (GCTC)
Star City, Russia
ESA Headquarters
Paris, France
H-II Launch Control
Tanegashima , Japan
JAXA Headquarters
Tokyo, Japan

Canada

Canadian Space Agency (CSA)

Mobile Servicing System (MSS) Operations Complex (MOC)

Located in Saint-Hubert, Quebec, the MSS Operations Complex is composed of the following facilities:

- Remote Multipurpose Support Room (RMPSR)
- Operations Engineering Centre (OEC)
- MSS Operations and Training System (MOTS)
- Canadian MSS Training Facility (CMTF)

These facilities provide the resources, equipment and expertise for the engineering and monitoring of the MSS, as well as the facilities for training crew and flight controllers on Canadian robotic systems.

Payload Telescience Operations Centre (PTOC)

The PTOC in Saint Hubert supports real-time operations for Canadian payloads onboard the ISS.

http://www.asc-csa.gc.ca

Europe

European Space Agency (ESA)

European Space Research and Technology Center (ESTEC)

The European Space Research and Technology Center in Noordwijk, the Netherlands, is the largest ESA establishment, a test center and hub for European space activities. It has responsibility for the technical preparation and management of ESA space projects and provides technical support to ESA's ongoing satellite, space exploration, and human space activities.

Columbus Control Center (Col-CC)

The COL-CC, located at the German Aerospace Center (DLR), in Oberpfaffenhofen, near Munich, Germany, controls and operates the Columbus laboratory and coordinates the operation of European experiments.

European Astronaut Center (EAC)

The European Astronaut Center of the European Space Agency is situated in Cologne, Germany. It was established in 1990 and is the home base of the 13 European astronauts who are members of the European Astronaut Corps.

User Centers

User Support and Operation Centers (USOCs) are based in national centers distributed throughout Europe. These centers are responsible for the use and implementation of European payloads aboard the ISS.

http://www.esa.int

Japan

Japan Aerospace Exploration Agency (JAXA)

In addition to the JAXA headquarters in Tokyo and other field centers throughout the country, Tsukuba Space Center and Tanegashima Launch Facility are JAXA's primary ISS facilities.

Tsukuba Space Center (TKSC)

JAXA's Tsukuba Space Center (TKSC), located in Tsukuba Science City, opened its doors in 1972. The TKSC is a consolidated operations facility with world-class equipment, testing facilities, and crew training capabilities. The Japanese Experiment Module (JEM) "Kibo" was developed and tested at TKSC for the ISS. The Kibo Control Center plays an important role in control and tracking of the JEM.

Tanegashima Space Center (TNSC)

The Tanegashima Space Center is the largest rocket-launch complex in Japan and is located in the south of Kagoshima Prefecture, along the southeast coast of Tanegashima. The Yoshinobu launch complex is on site for H-IIA and H-IIB launch vehicles. There are also related developmental facilities for test firings of liquid- and solid-fuel rocket engines.

http://www.jaxa.jp/index_e.html

Russia

Roscosmos, Russian Federal Space Agency

Roscosmos oversees all Russian human space flight activities.

Moscow Mission Control Center (TsUP)

Moscow Mission Control Center is the primary Russian facility for the control of Russian human spaceflight activities and operates the ISS Russian segment. It is located in Korolev, outside of Moscow, at the Central Institute of Machine building (TsNIIMASH) of Roscosmos.

Gagarin Research and Test Cosmonaut Training Center (GCTC)

The Gagarin cosmonaut training center, at Zvezdny Gorodok (Star City), near Moscow, provides full-size trainers and simulators of all Russian ISS modules, a water pool used for spacewalk training, centrifuges to simulate g-forces during liftoff, and a planetarium used for celestial navigation.

Baikonur Cosmodrome

The Baikonur Cosmodrome, in Kazakhstan, is the chief launch center for both piloted and unpiloted space vehicles. It supports the Soyuz and Proton launch vehicles and plays an essential role in the deployment and operation of the ISS.

http://www.roscosmos.ru

United States of America

National Aeronautics and Space Administration (NASA)

NASA Headquarters (HQ)

NASA Headquarters in Washington, DC, exercises management over the NASA Field Centers, establishes management policies, and analyzes all phases of the ISS program.

Johnson Space Center (JSC)

Johnson Space Center in Houston, TX, directs the ISS program. Mission control operates the U.S. On-orbit Segment (USOS) and manages activities across the ISS in close coordination with the international partner control centers. JSC is the primary center for spacecraft design, development, and mission integration. JSC is also the primary location for crew training. Commercial Resupply Services contracts with OrbitalATK and SpaceX U.S. commercial companies are managed by JSC to provide reliable commercial cargo transportation that is critical for the continued support of the ISS research community. NASA's contract strategy enabled the contractor's responsibility to provide an end to end service while meeting milestone payment and mission success criteria. NASA's key focus is managing the research, cargo and safety aspects for each mission to the ISS. A follow-on contract for ISS services will expand the vehicle research capability and promote further U.S. space industry competition.

Kennedy Space Center (KSC)

Kennedy Space Center in Cape Canaveral, FL, prepared the ISS modules and Space Shuttle orbiters for each mission, coordinated each countdown, and managed Space Shuttle launch and post-landing operations. The goal of NASA's Commercial Crew Program (CCP) Commercial Crew Transportation Capability will enable NASA to ensure crew transportation system is safe, reliable and cost-effective. The certification process will assess progress throughout the production and testing of one or more integrated space transportation systems, which include rockets, spacecraft, missions and ground operations. Requirements also include at least one crewed flight test to the space station before NASA certification of a U. S. spacecraft can be granted. CCP missions will then provide ISS crew rotation and double the amount of critical science research being performed on-orbit.

Marshall Space Flight Center (MSFC)

Marshall Space Flight Center's Payload Operations and Integration Center (POIC) controls the operation of U.S. experiments and coordinates partner experiments aboard the ISS. MSFC oversaw development of most U.S. modules and the ISS ECLSS system.

Telescience Support Centers (TSCs)

Telescience Support Centers around the country are equipped to conduct science operations on board the ISS. These TSCs are located at Marshall Space Flight Center in Huntsville, AL; Ames Research Center (ARC) in Moffett Field, CA; Glenn Research Center (GRC) in Cleveland, OH; and Johnson Space Center in Houston, TX.

http://www.nasa.gov

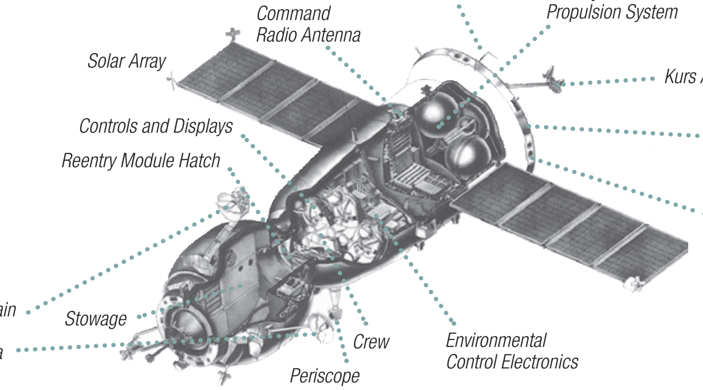
Soyuz	Proton	H-IIB	Shuttle 1998-2011	Ariane 2008-2015
Roscosmos Russia		JAXA Japan	NASA United States	ESA Europe

	Russia		Japan	U.S.	Europe
	Soyuz SL-4	Proton SL-12	H-IIB	Space Shuttle	Ariane 5
First launch to ISS	2000	1998	2009	1998	2008
Launch site(s)	Baikonur Cosmodrome	Baikonur Cosmodrome	Tanegashima Space Center	Kennedy Space Center	Guiana Space Center
Launch performance payload capacity	7,150 kg (15,750 lb)	20,000 kg (44,000 lb)	16,500 kg (36,400 lb)	18,600 kg (41,000 lb) 105,000 kg (230,000 lb), orbiter only	18,000 kg (39,700 lb)
Return performance payload capacity	N/A	N/A	N/A	18,600 kg (41,000 lb) 105,000 kg (230,000 lb), orbiter only	N/A
Number of stages	2 + 4 strap-ons	4 + 6 strap-ons	2 + 4 strap-ons	1.5 + 2 strap-ons	2 + 2 strap-ons
Length	49.5 m (162 ft)	57 m (187 ft)	57 m (187 ft)	56.14 m (18.2 ft) 37.24 m (122.17 ft), orbiter only	51 m (167 ft)
Mass	310,000 kg (683,400 lb)	690,000 kg (1,521,200 lb)	531,000 kg (1,170,700 lb)	2,040,000 kg (4,497,400 lb)	746,000 kg (1,644,600 lb)
Launch thrust	6,000 kN (1,348,800 lbf)	9,000 kN (2,023,200 lbf)	5,600 kN (1,258,900 lbf)	34,677 kN (7,795,700 lbf)	11,400 kN (2,562,820 lbf)
Payload examples	Soyuz Progress Pirs	Service Module Functional Cargo Block (FGB) Multipurpose Lab Module (MLM)	H-II Transfer Vehicle (HTV)	Shuttle Orbiter, Nodes 1–3, U.S. Lab, JEM, Truss elements, Airlock, SSRMS	Ariane Automated Transfer Vehicle (ATV)

Soyuz

Russian Federal Space Agency (Roscosmos)/ S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

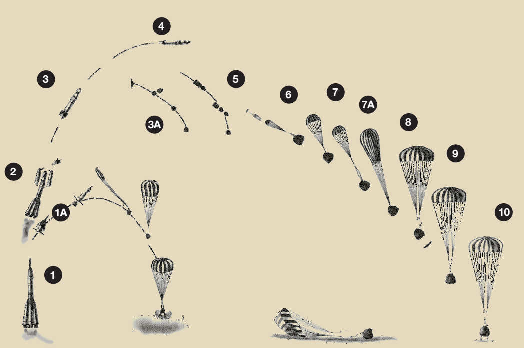
Soyuz spacecraft have been in use since the mid-1960s and have been upgraded periodically. Soyuz can support independently three suited crewmembers for up to 5.2 days and be docked to the ISS up to 200 days. The vehicle has an automatic docking system and may be piloted automatically or by a crewmember. The Soyuz provides transportation of Crewmembers and cargo to/from the ISS. The Soyuz is comprised of 3 modules, the Descent module is the only one which returns to Earth.



Soyuz spacecraft approaching the International Space Station.

Cosmonaut Anton Shkaplerov reviews procedures in the descent module of a docked Soyuz TMA-1 spacecraft.

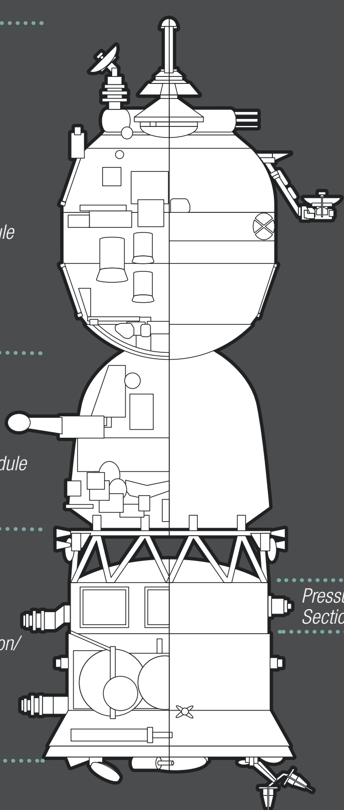
Mission Sequence



Launch and Aborts
- 1 Launch
- 1A Abort using escape rocket
- 2 Escape rocket jettison, nose shroud separation (160 seconds in full)
- 3 Staging (186 seconds)
- 3A Abort by separation of Soyuz
- 4 Orbital velocity (526 seconds)

Return
- 5 Soyuz retrofire, orbital module separation, reentry module separation
- 6 Pilot parachute deploys
- 7 Drogue parachute deploys
- 7A Main parachute reefed
- 8 Main parachute fully deployed
- 9 Reentry heatshield jettison
- 10 Landing, retro rocket firing

Launch mass	7,190 kg (15,851 lb)
Descent module	2,900 kg (6,393 lb)
Orbital module	1,300 kg (2,866 lb)
Instrumentation/ propulsion module	2,600 kg (5,732 lb)
Delivered payload with two crewmembers with three crewmembers	 230 kg (507 lb) 170 kg (375 lb)
Returned payload	50 kg (110 lb)
Length	7 m (22.9 ft)
Maximum diameter	2.7 m (8.9 ft)
Diameter of habitable modules	2.2 m (7.2 ft)
Solar array span	10.6 m (34.8 ft)
Volume of orbital module	6.5 m³ (229.5 ft³)
Volume of descent module	4 m³ (141.3 ft³)
Descent g-loads	4–5 g
Final landing speed	2 m/s (6.6 ft/s)



Progress

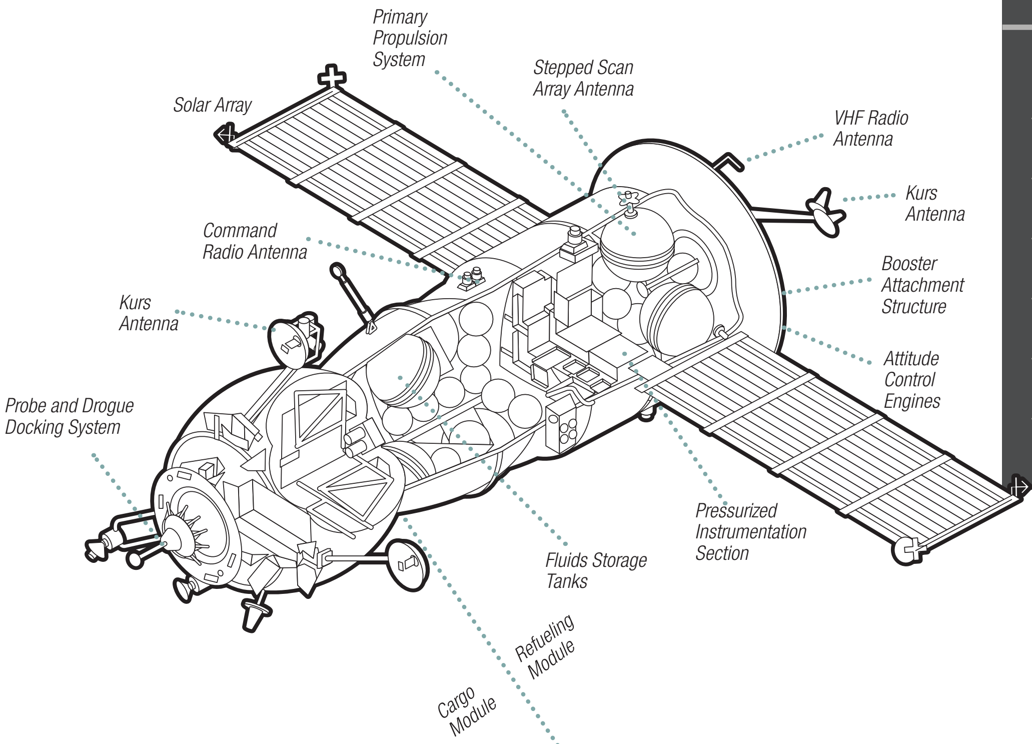
Russian Federal Space Agency (Roscosmos)/ S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

Progress is a resupply vehicle used for dry cargo, propellant, water, and gas deliveries to the ISS. Once docked to the ISS, Progress engines can boost the ISS to higher altitudes and control the orientation of the ISS in space. Typically, four Progress vehicles bring supplies to the ISS each year. Progress is based upon the Soyuz design, and it can either work autonomously or can be flown remotely by crewmembers aboard the ISS. After a Progress vehicle is filled with trash from the ISS, and after undocking and deorbit, it is incinerated in Earth's atmosphere at the end of its mission. During its autonomous flight (up to 30 days), Progress can serve as a remote free-flying research laboratory for conducting space experiments.

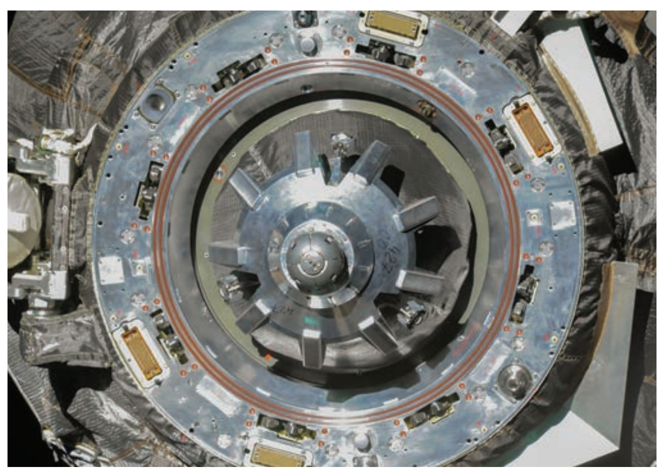
Length	7.4 m (24.3 ft)
Maximum diameter	2.7 m (8.9 ft)
Span with solar arrays	10.7 m (35.1 ft)
Launch mass	7,440 kg (16,402 lb)
Cargo upload capacity	2,250 kg (4,960 lb)
Pressurized habitable volume	7.0 m³ (247.2 ft³)
Engine thrust	2,942 N (661 lbf)
Orbital life	6 mo
Dry cargo max	1,700 kg (3,748 lb)
Refueling propellant	870 kg (1,918 lb)

Cargo Load

	Maximum	Typical*
Dry cargo such as bags	1,800 kg (3,968 lb)	1,070 kg (2,360 lb)
Water	420 kg (925 lb)	300 kg (660 lb)
Air	50 kg (110 lb)	47 kg (103 lb)
Refueling propellant	1,700 kg (3,748 lb)	870 kg (1,918 lb)
Reboost propellant	250 kg (550 lb)	250 kg (550 lb)
Waste capacity	2,140 kg (4,718 lb)	2,000 kg (4,409 lb)



Progress Spacecraft connected to the Pirs Docking Compartment 1 (DC1).



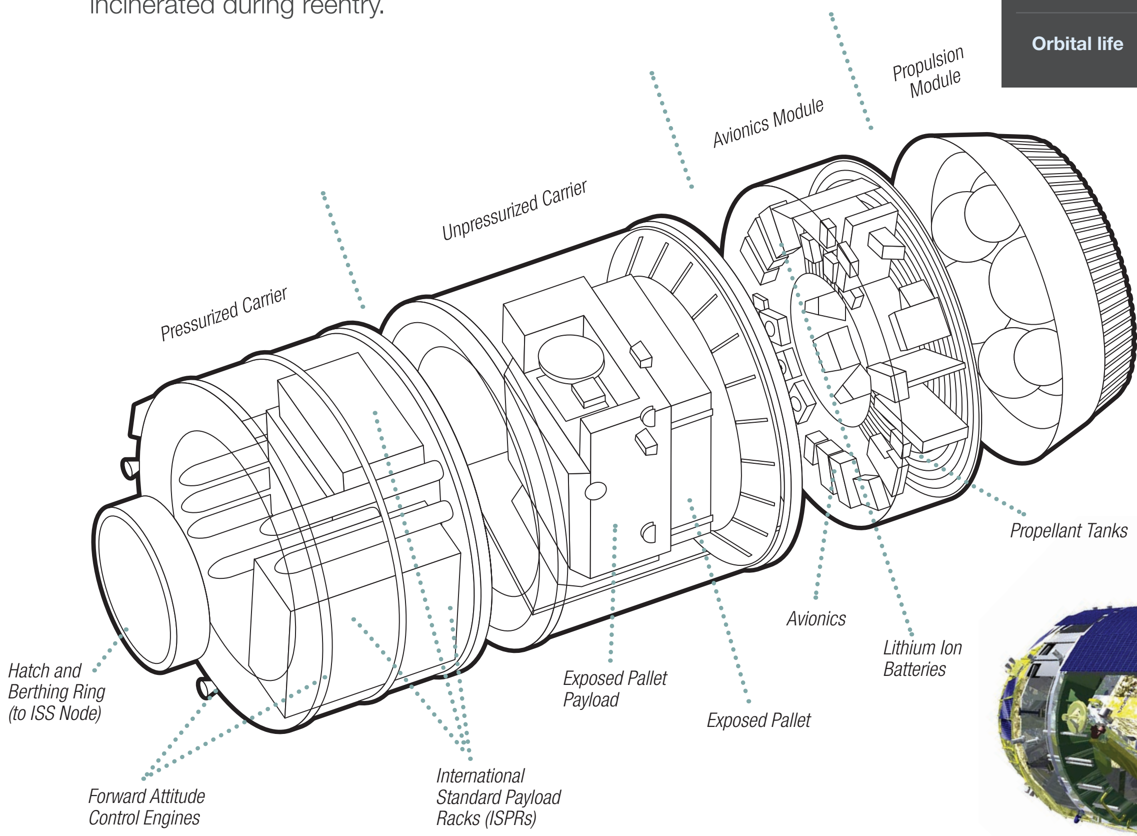
This close-up view shows the docking mechanism of the unpiloted Russian ISS Progress resupply ship as it undocks from the International Space Station's Pirs Docking Compartment.

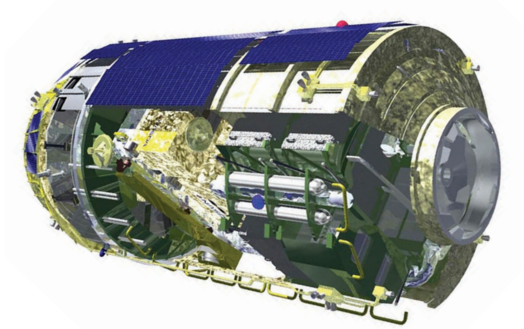
JAXA H-II Transfer Vehicle (HTV)

Japan Aerospace Exploration Agency (JAXA)/ Mitsubishi Heavy Industries, Ltd.

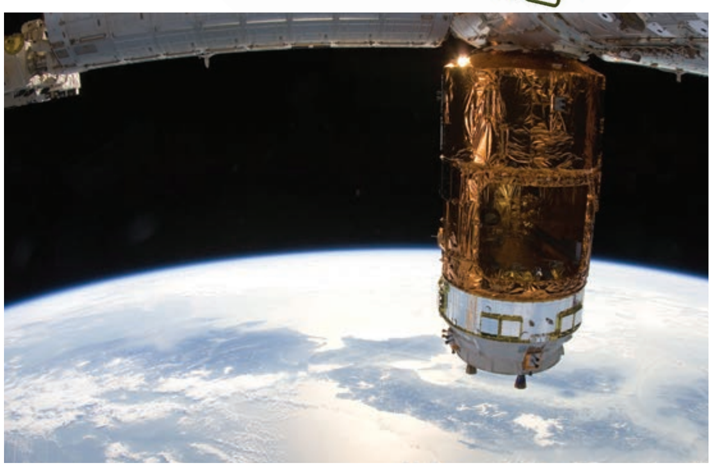
The H-II Transfer Vehicle is an autonomous logistical resupply vehicle designed to berth to the ISS using the Space Station Remote Manipulation System (SSRMS). HTV offers the capability to carry logistics materials in both its internal pressurized carrier and in an unpressurized carrier for exterior placement. It is launched on the H-II unmanned launch vehicle and can carry dry cargo, gas and water. After fresh cargo is unloaded at the ISS, the HTV is loaded with trash and waste products; after unberthing and deorbit, it is incinerated during reentry.

Length	9.2 m (30 ft)
Maximum diameter	4.4 m (14.4 ft)
Launch mass	16,500 kg (36,375 lb)
Cargo upload capacity	5,500 kg (12,125 lb)
Pressurized habitable volume	14 m³ (495 ft³)
Unpressurized volume	16 m³ (565 ft³)
Orbital life	6 mo





Tanegashima Launch Facility control room.



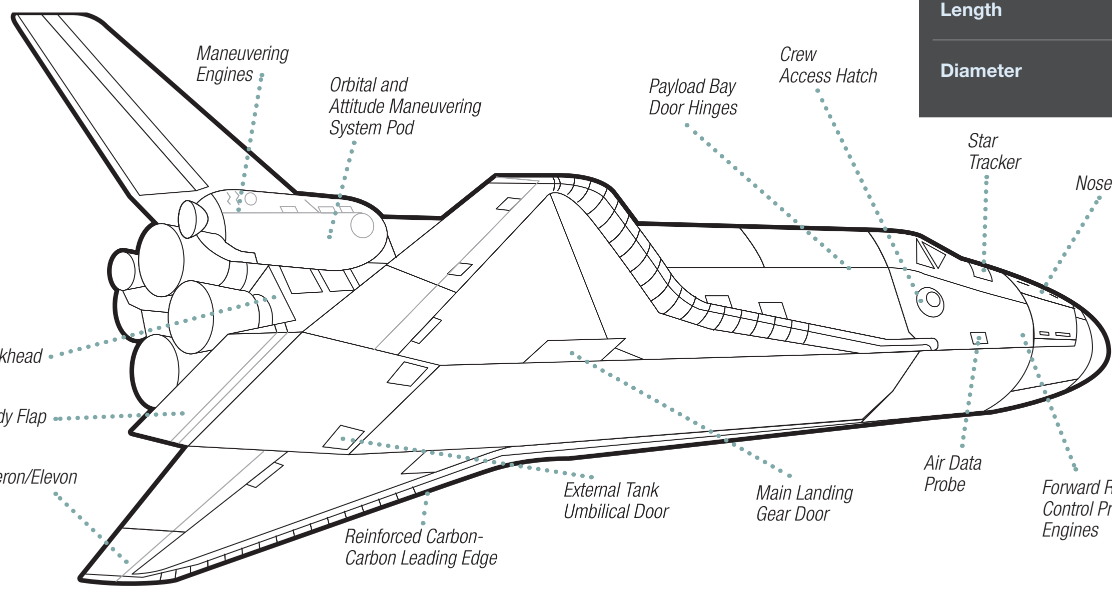
View of H-II Transfer Vehicle (HTV) docked to Node 2.

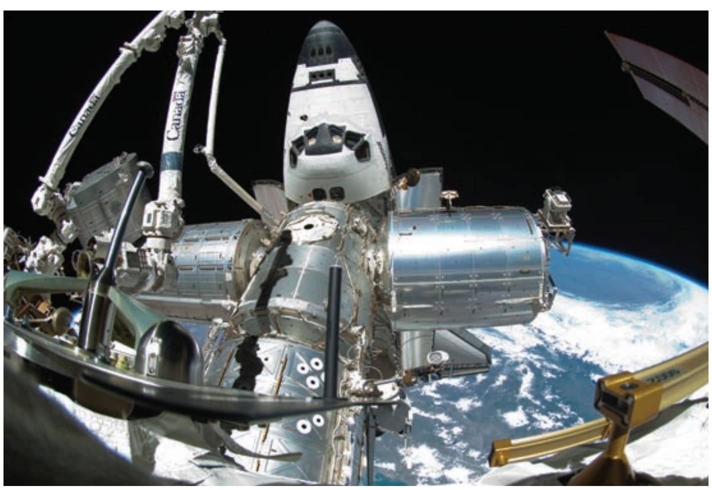
Space Shuttle Orbiter/ Discovery, Atlantis, Endeavour

NASA/Boeing
1981-2011

Length	37.2 m (122.2 ft)
Height	17.3 m (56.7 ft)
Wingspan	23.8 m (78 ft)
Typical mass	104,000 kg (230,000 lb)
Cargo capacity	16,000 kg (35,000 lb) (typical launch and return to ISS)
Pressurized habitable volume	74 m^3 (2,625 ft^3)
Mission length	7–16 days, typical
Number of crew	7, typical
Atmosphere	oxygen-nitrogen
Cargo Bay	
Length	18.3 m (60 ft)
Diameter	4.6 m (15 ft)

Between the first assembly launch using the Space Shuttle on December 4, 1998, and the final landing on July 21, 2011, NASA's space shuttle fleet – Discovery, Atlantis and Endeavour – helped construct the largest structure in space, the International Space Station. The Space Shuttle was used to deliver most of the ISS modules and major components. It also provided crew rotation (beginning in November, 2001), science and maintenance cargo delivery, and is the only vehicle that provided the capability to return significant payloads.





A portion of the International Space Station and the docked space shuttle Endeavour.

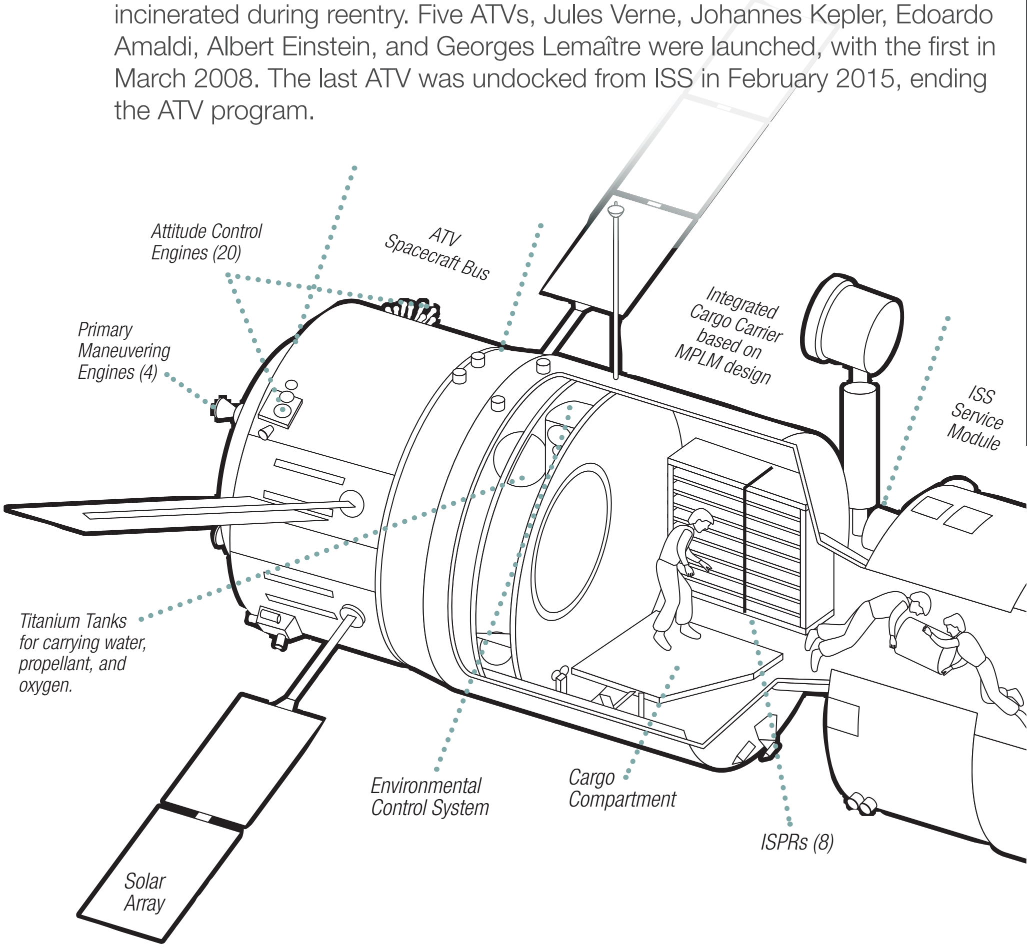

Space shuttle Atlantis launches from Launch Pad 39A at Kennedy Space Center on the STS-135 mission, the final flight of the Space Shuttle Program (SSP).

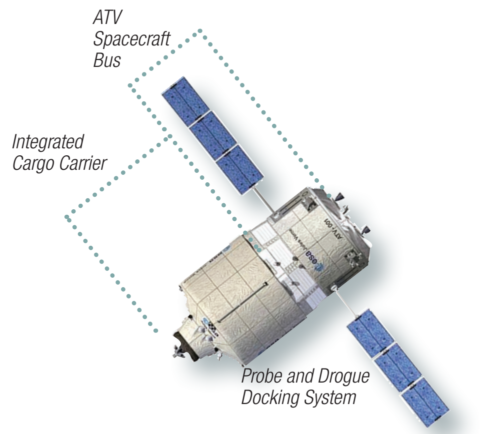
Automated Transfer Vehicle (ATV)

European Space Agency (ESA)/European Aeronautic Defence and Space Co. (EADS) 2008-2015

The European Space Agency Automated Transfer Vehicle was an autonomous logistical resupply vehicle that provided the crew with dry cargo, atmospheric gas, water, and propellant. After the cargo was unloaded, the ATV was reloaded with trash and waste products, undocked, and was incinerated during reentry. Five ATVs, Jules Verne, Johannes Kepler, Edoardo Amaldi, Albert Einstein, and Georges Lemaître were launched, with the first in March 2008. The last ATV was undocked from ISS in February 2015, ending the ATV program.

Length	10.3 m (33.8 ft)
Maximum diameter	4.5 m (14.8 ft)
Span across solar arrays	22.3 m (73.2 ft)
Launch mass	20,750 kg (45,746 lb)
Cargo upload capacity	7,667 kg (16,903 lb)
Engine thrust	1,960 N (441 lbf)
Orbital life	6 mo
Cargo Load	
Dry cargo such as bags	5,500 kg (12,125 lb)
Water	840 kg (1,852 lb)
Air (O_2, N_2)	100 kg (220 lb)
Refueling propellant	860 kg (1,896 lb)
Reboost propellant	4,700 kg (10,360 lb)
Waste capacity	6,500 kg (14,330 lb)





ESA astronaut André Kuipers floats into the ATV.

View of European Space Agency (ESA) Edoardo Amaldi Automated Transfer Vehicle-3 (ATV-3) approaching the International Space Station (ISS).

Commercialization

NASA, working with the other ISS International Partners, will continue to foster greater use of the ISS platform, for both research and commercial activities, while using the ISS as a base for expanding the commercial use of low Earth orbit (LEO). NASA remains the primary supplier of capabilities and services in LEO, such as habitation systems, power, cooling, crew health equipment, upmass and sample return, research facilities, cold stowage, crew time, and data transmission. It is the goal of NASA to evolve these systems onboard ISS in such a way that they will support market driven commercial research. NASA is also fostering new commercial markets in LEO through its innovative cargo resupply services and crew transportation contracts.

Requirements and Benefits

Commercial Crew Requirements for International Space Station Missions

- Transport 4 NASA or NASA-sponsored crew members
- Transport 220.5 pounds of pressurized cargo
- Stay on orbit docked to the station for up to 210 days
- Serve as a safe haven and act as a lifeboat in case of an emergency
- Able to quickly return to Earth for time-sensitive cargo

Commercial Crew Benefits

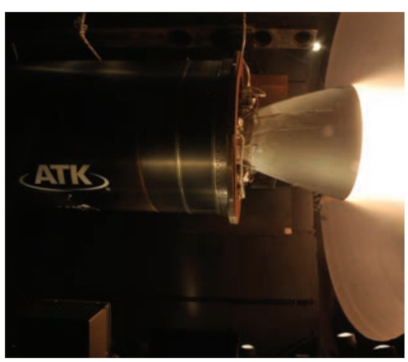
- Cost-Effective: Developing safe, reliable and cost-effective crew transportation to the International Space Station that reduces reliance on foreign systems.
- American Ingenuity: Lowering the cost of access to space and enhancing the U.S. industrial base.
  - NASA's Commercial Crew Program partner companies, and their providers and suppliers, are leading a truly national effort.
  - More than 150 companies across 37 states are applying their most efficient and innovative approaches to get astronauts back into space on American-led spacecraft and rockets.
  - American companies have the flexibility to determine the design details and development approach for state-of-the-art U.S.-based transportation systems to and from the International Space Station and to develop other space markets in low-Earth orbit.
- Journey to Mars: Using limited resources wisely to enable deep space capabilities.
  - NASA is on a dual path for human exploration. By turning over low-Earth orbit flights to the commercial aerospace industry, NASA can pursue the challenges of deep space exploration and our journey to Mars.
- Focus on Science: Two times more research.
  - The International Space Station crew spends about 35 hours each week conducting research in Earth, space, physical and biological sciences to advance scientific knowledge for the benefit of people living on Earth.
  - NASA requires these spacecraft to carry a crew of four, enabling the station crew to expand from six to seven astronauts and cosmonauts.
  - It only takes six crew members to maintain the station, so an extra person translates to 40 additional hours of crew time for research.

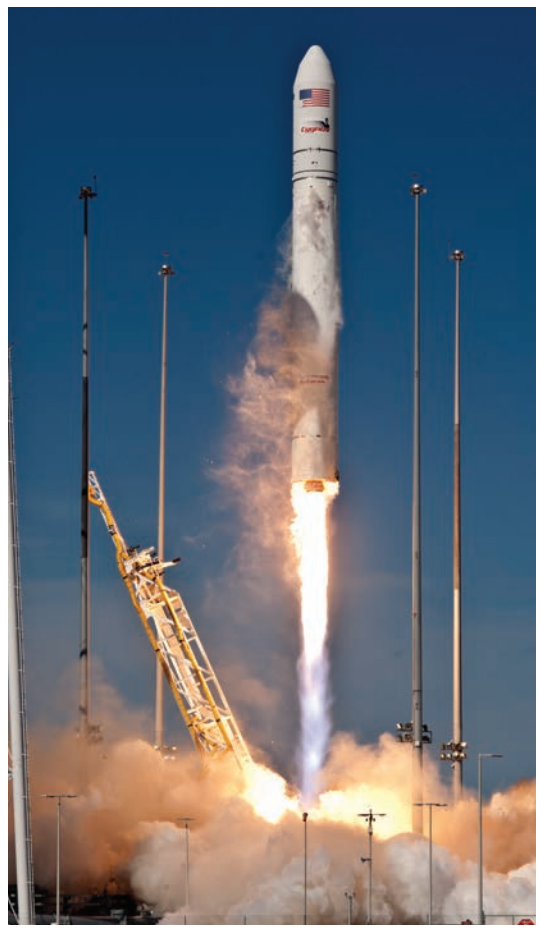
Antares and Cygnus

Orbital ATK

The Cygnus missions are launched on an Antares from the NASA Wallops Flight Facility on Wallops Island, Virginia. The first stage is powered by two RD-181 engines, and the second stage is a Castor 30XL. The spacecraft that launches on the Antares is called the Cygnus. The Cygnus spacecraft is an automated logistical resupply vehicle designed to rendezvous with the ISS and is grappled and berthed using the Space Station Remote Manipulator System (SSRMS). The Cygnus has a Pressurized Cargo Module (PCM) that brings cargo (logistics and utilization) to the ISS. The other section of the spacecraft is the Service Module (SM), which houses the avionics, electrical, propulsion, and guidance systems. After cargo is transferred to the ISS, Cygnus is then loaded with trash for disposal. Once the mission is complete, the Cygnus unberths from the ISS and is destroyed (incinerated) upon re-entry into the Earth's atmosphere.

Antares	
Height	40.1 m
Diameter	3.9 m
Mass at launch	290,000 - 310,000 kg
First stage thrust	4.17 MN
Second stage thrust	533 kN
Cygnus	
PCM Length	5.1 m
Diameter	3.05 m
Maximum Upmass Pressurized	3200 -3500 kg
Maximum Downmass Pressurized	3500 kg
Maximum Upmass Unpressurized	0
Maximum Downmass Unpressurized	0
Payload volume Pressurized	26 m^3





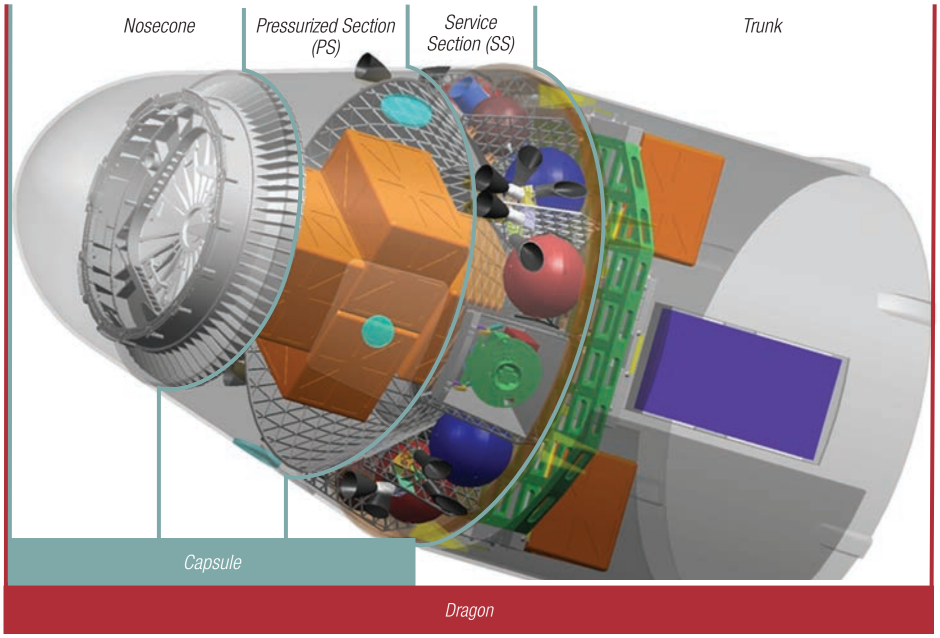
Falcon 9 and Dragon

Space Exploration Technologies (SpaceX)

The SpaceX missions are launched on a Falcon 9 from Launch Complex 40 at Cape Canaveral Air Force Station, Florida. The first stage is powered by nine SpaceX Merlin engines, and the second stage is also a single SpaceX Merlin engine. The spacecraft that launches on the Falcon 9 is called the Dragon.

The Dragon spacecraft is an automated logistical resupply vehicle designed to rendezvous with the ISS and is grappled and berthed using the Space Station Remote Manipulator System (SSRMS).

The Dragon has a capsule section for delivering pressurized cargo, and another section called the "trunk" is used to deliver unpressurized cargo to the ISS. Once the mission is complete, the Dragon unberths from the ISS. The trunk is jettisoned and destroyed during reentry into the atmosphere, whereas the Dragon capsule, with its valuable pressurized return cargo, reenters the Earth's atmosphere and lands in the ocean with the use of parachutes. The Dragon capsule is recovered by SpaceX and is transported back to their facility for return cargo processing.



SpaceX's Dragon cargo capsule is seen here docked to the Earth facing port of the Harmony module.

Falcon 9	
Height	48.1 m (157.80 ft)
Diameter	3.66 m (12 ft)
Mass at launch	313,000 kg (690,047 lb)
First stage thrust	3.80 MN (854,000 lb)
Second stage thrust	414 kN (93,000 lb)
Dragon	
Height	5.1 m (16.73 ft)
Diameter	3.66 m (12 ft)
Maximum Pressurized Cargo Up mass/volume	3,310 kg (7,297 lb) 6.8 m³ (240 ft³)
Down mass/volume	2,500 kg (5,512 lb) 6.8 m³ (240 ft³)
Maximum Unpressurized Cargo Up mass/volume	3,310 kg (7,297 lb) 14 m³ (494 ft³)
Down mass/volume	2,600 kg (5,732 lb) 14 m³ Disposed (494 ft³)
Payload volume Pressurized	10 m³ (245 ft³)
Unpressurized	14 m³ (490 ft³)

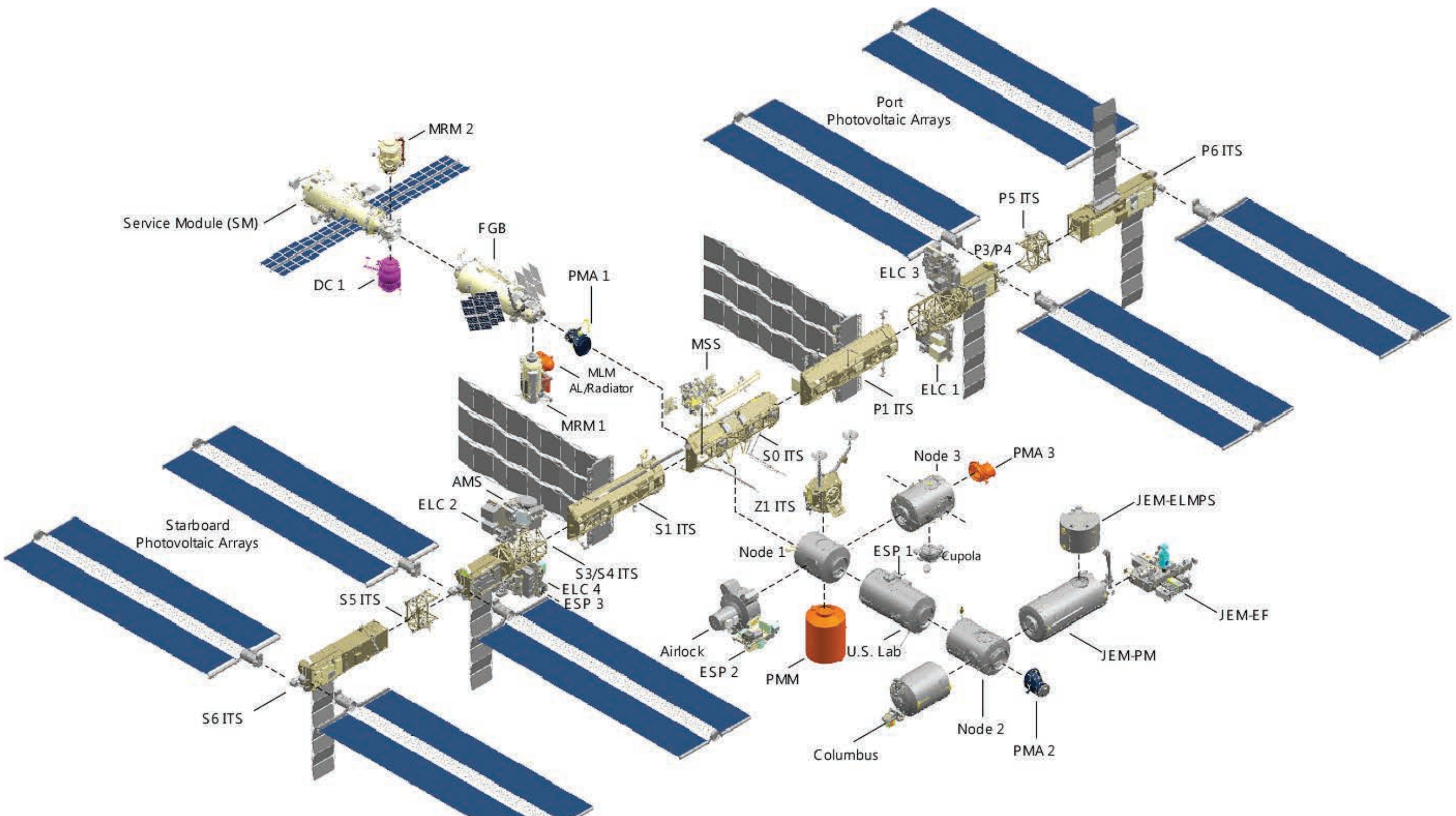
Assembly

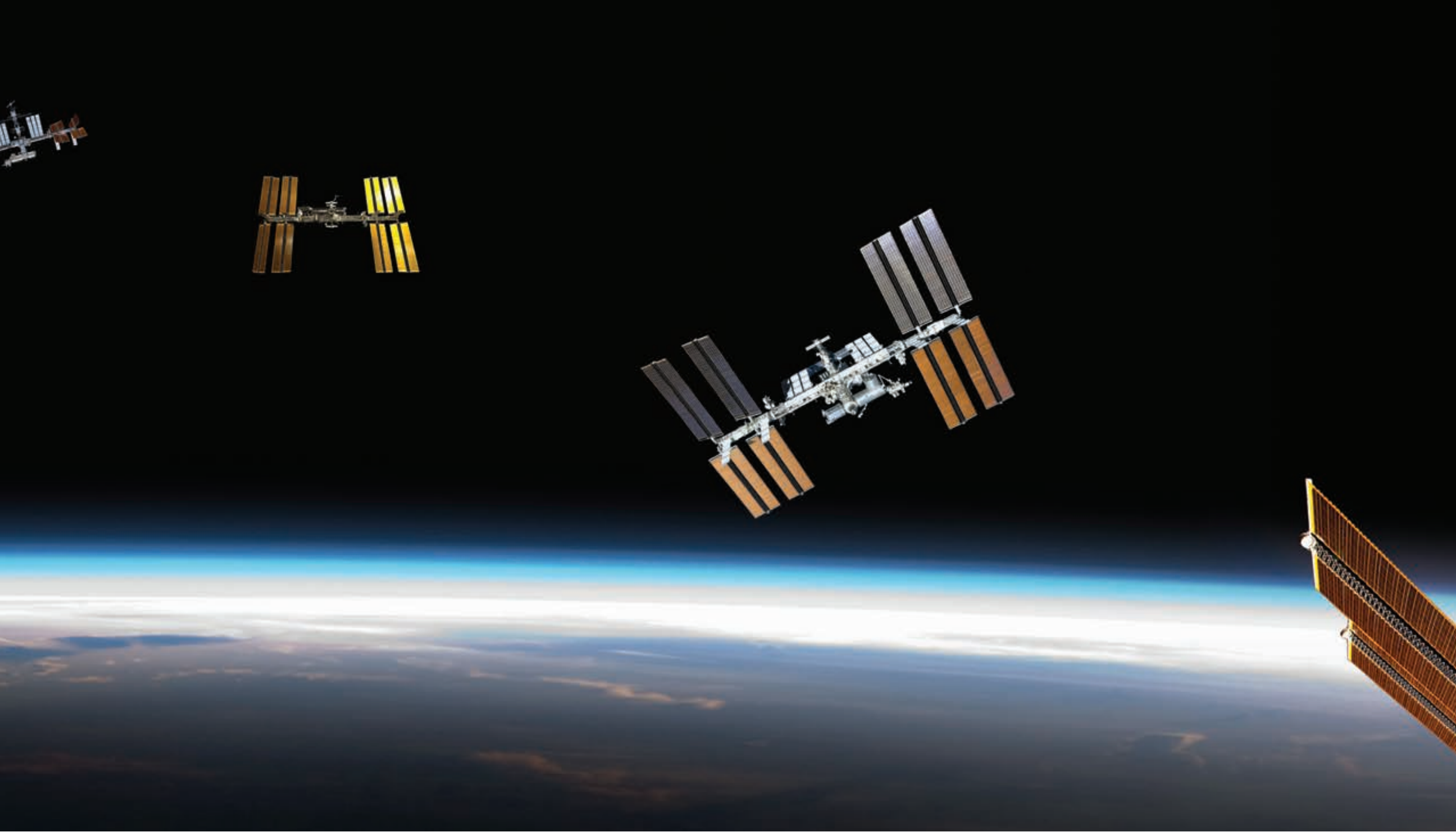
The ISS design evolved over a decade. Like a Lego set, each piece of the ISS was launched and assembled in space, using complex robotics systems and humans in spacesuits connecting fluid lines and electrical wires.

The ISS components were built in various countries around the world, with each piece performing once connected in space, a testament to the teamwork and cultural coordination.

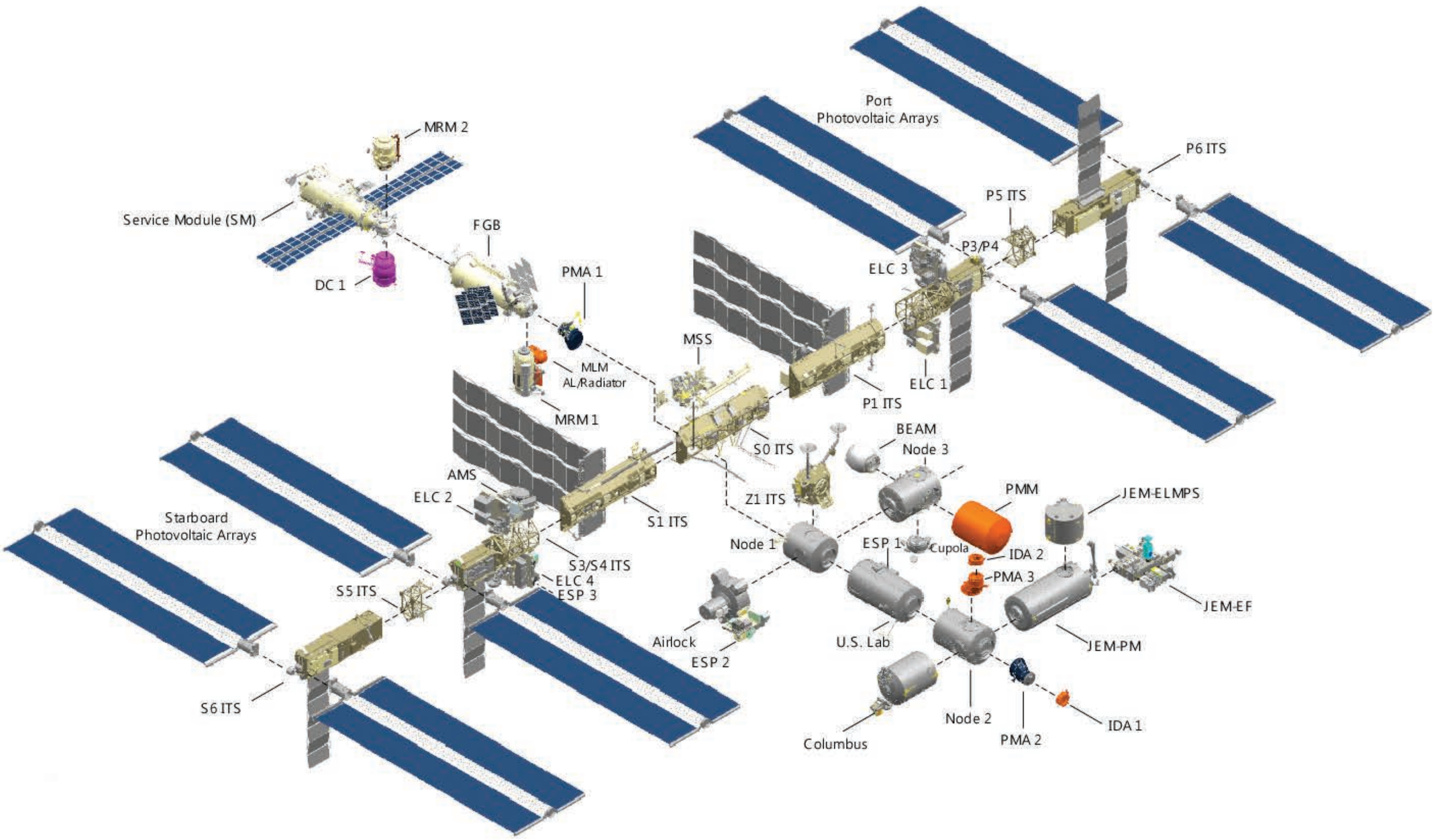
ISS Expanded View

ISS Expanded View prior to the ISS reconfiguration in the summer of 2015





ISS Expanded View post the ISS reconfiguration in the summer of 2015



Principal Stages in Construction

ISS stage number/letter conventions:

A=U.S. Assembly

E=European Assembly

J=Japanese Assembly

LF=Logistics

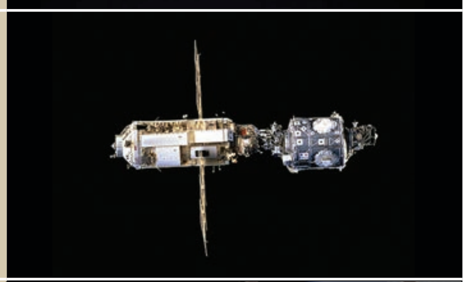
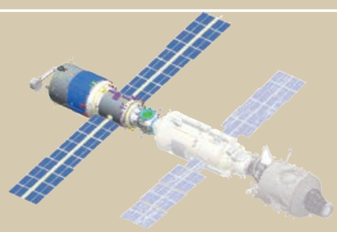
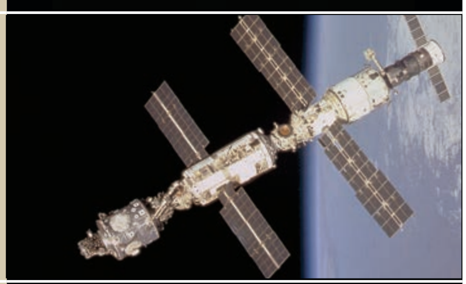
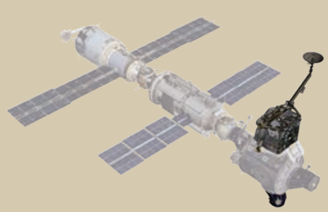
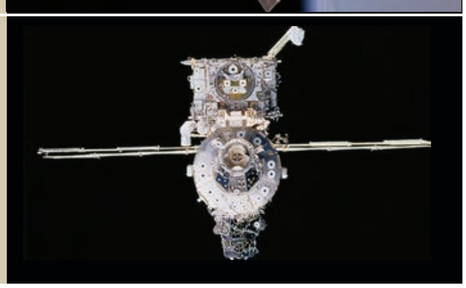
R=Russian Assembly

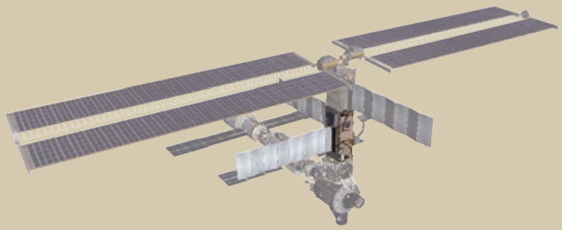
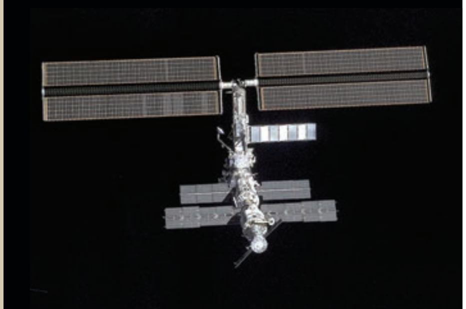
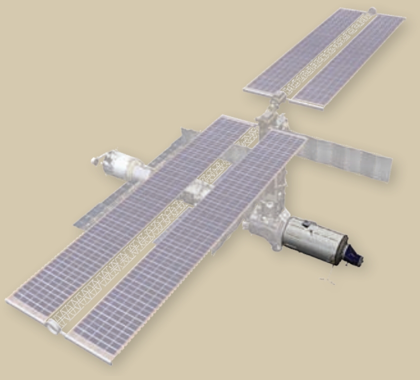
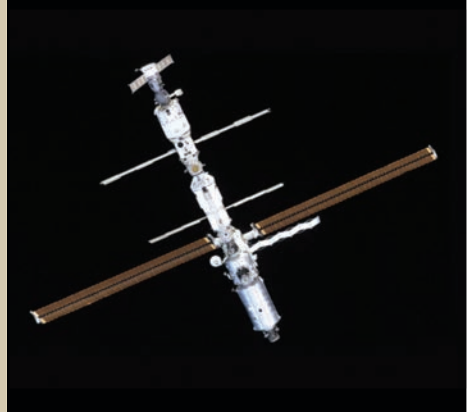
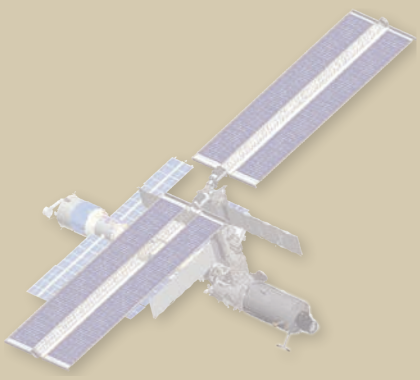
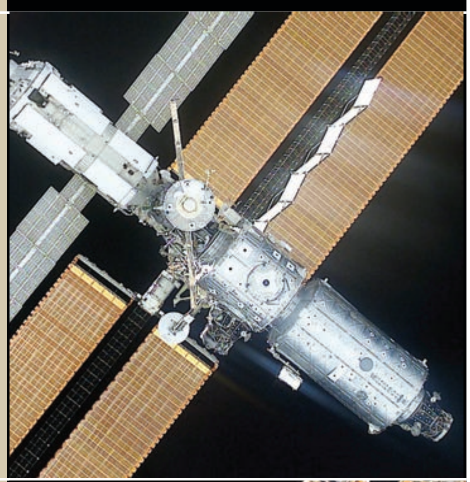
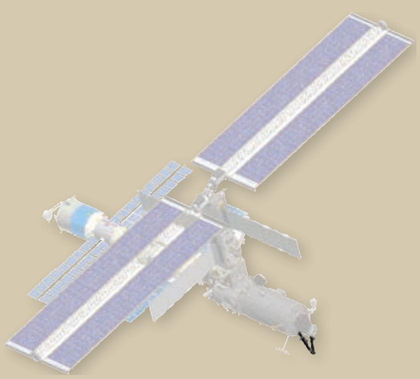
UF=Utilization

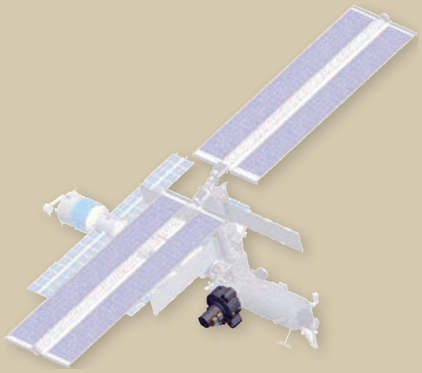
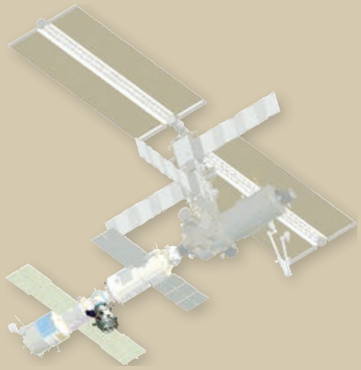
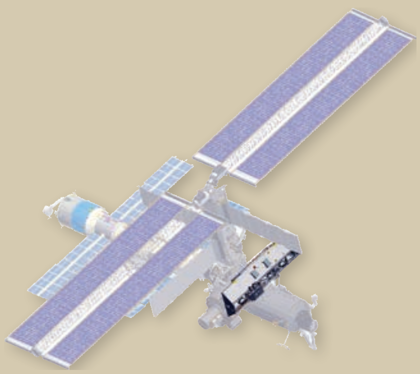
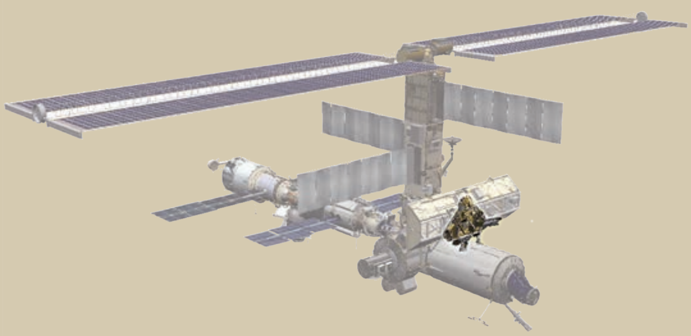
ULF=Utilization/Logistics

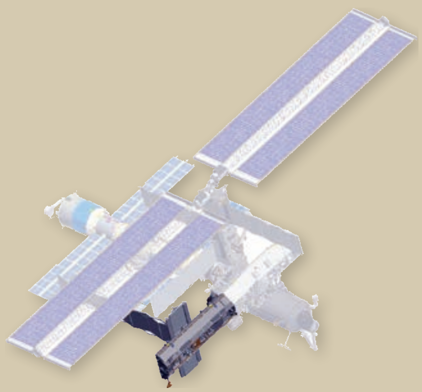
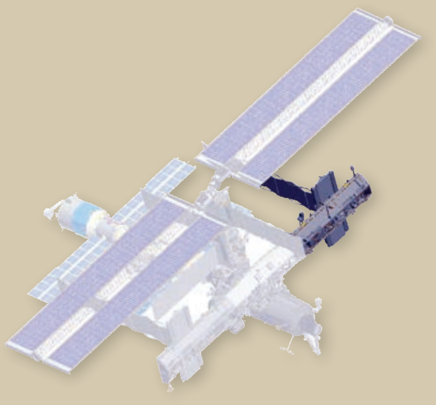
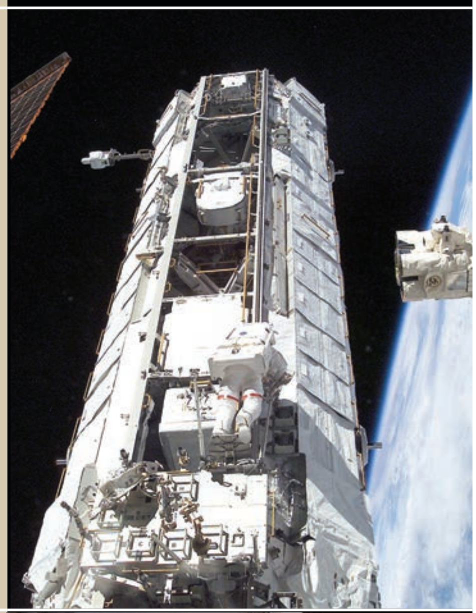
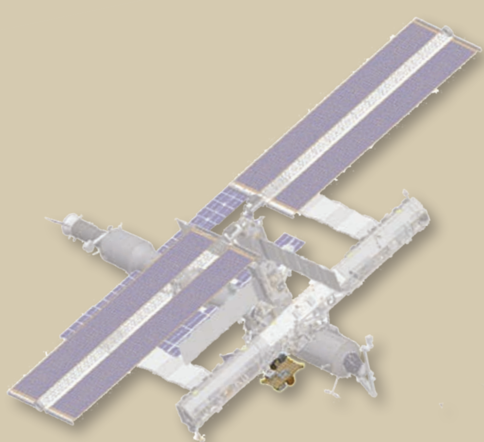
The ISS is the largest human made object ever to orbit the Earth. The ISS has a mass of 410,501 kg (905,000 lbs) and a pressurized volume of approximately 916 m3 (32,333 ft3). The ISS can generate up to 80 kilowatts of electrical power per orbit from solar arrays which cover an approximate area of 2,997 m2 (32,264 ft2). The ISS structure measures 95 m (311 ft) from the P6 to S6 trusses and 59 m (193 ft) from PMA2 to the Progress docked on the aft of the Russian Service Module. The ISS orbital altitude can range from 278-460 km (150-248 nautical miles) and is in an orbital inclination of 51.6 degrees. The ISS currently houses 6 crew members.

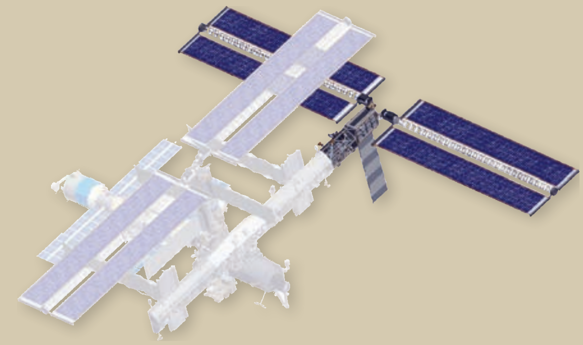
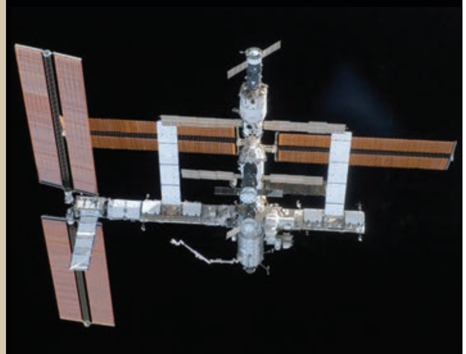
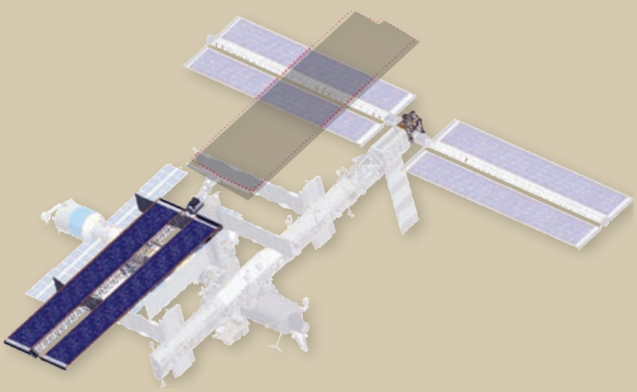
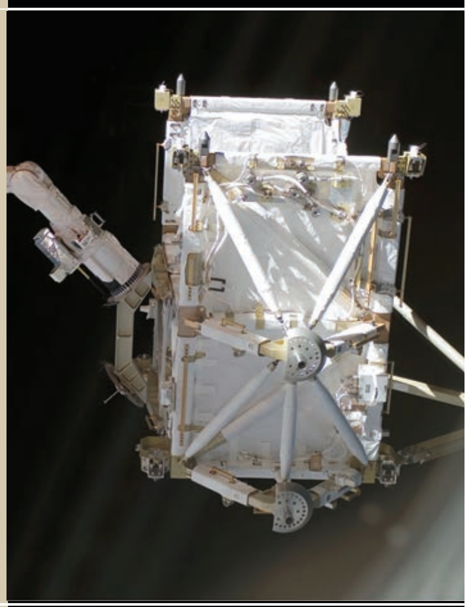
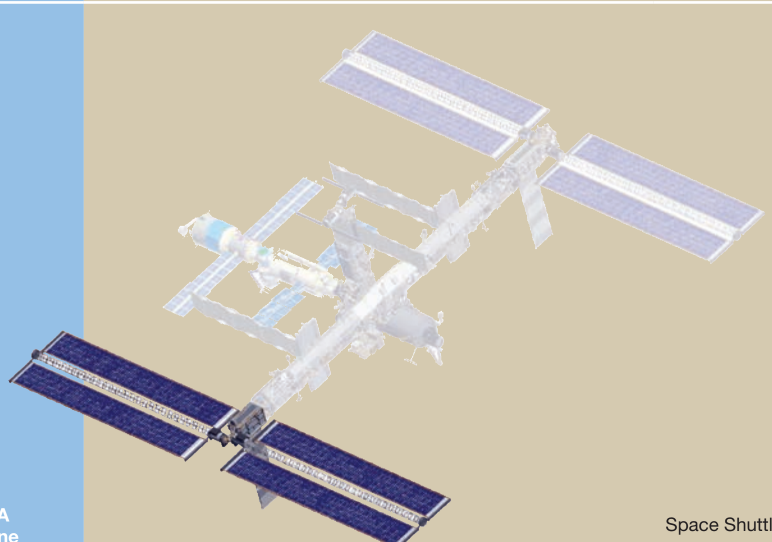
Building the ISS required 36 Space Shuttle assembly flights and 5 Russian launches. Currently, logistics and resupply are provided through a number of vehicles including the Russian Progress and Soyuz, Japanese H-II Transfer Vehicle (HTV), and commercial cargo vehicles (Dragon and Cygnus). Previous vehicles that have been retired include the Space Shuttle and the European Automated Transfer Vehicle (ATV).

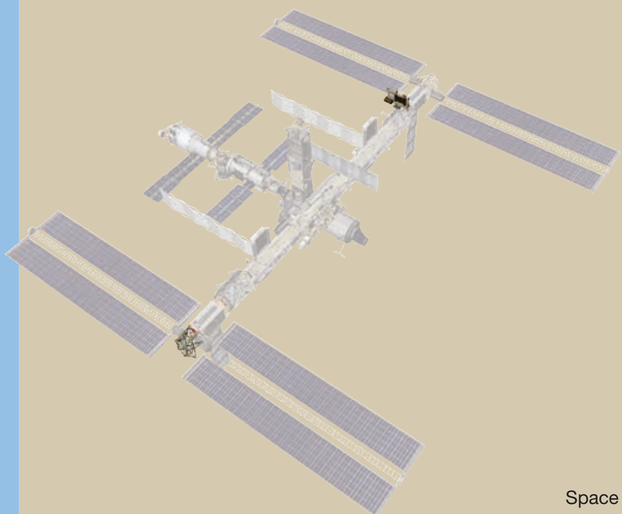
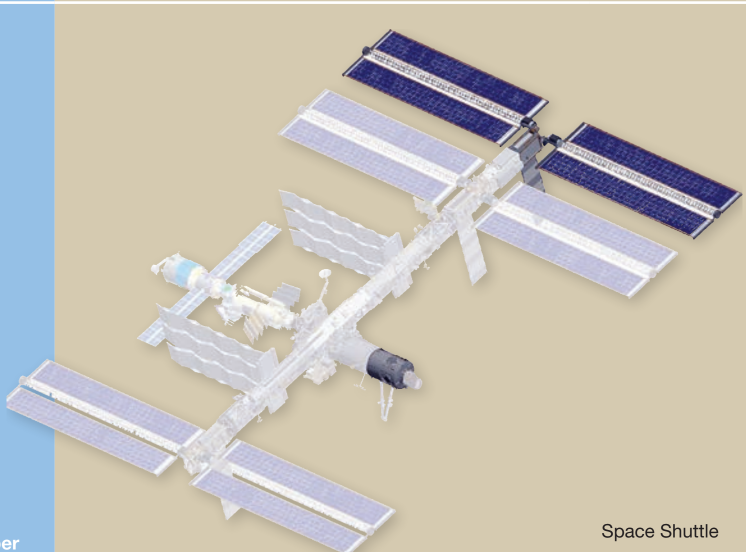
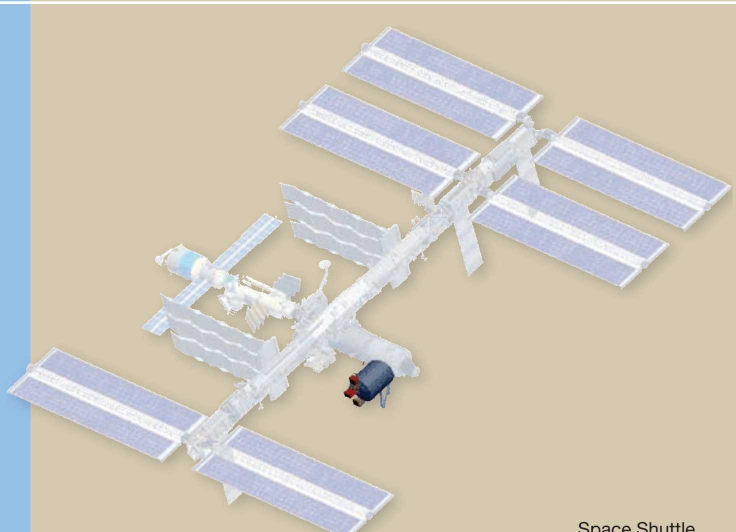
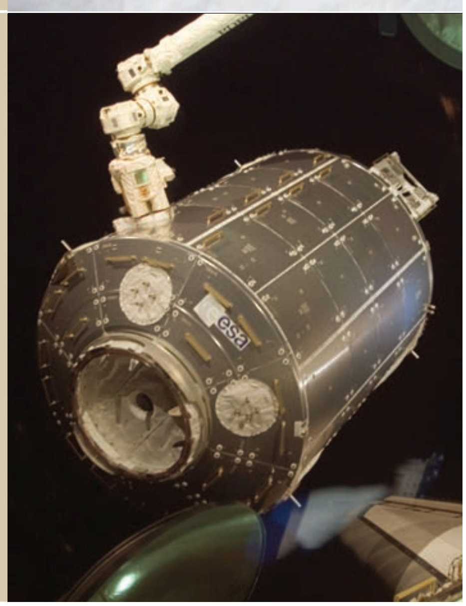
Stage/ Date	Element Added	Launch Vehicle	ISS Picture
1A/R November 1998	 Functional Cargo Block (FGB)	Proton	
2A December 1998	 Node 1, Pressurized Mating Adapter (PMA) 1, 2	Space Shuttle STS-88	
1R July 2000	 Service Module (SM)	Proton	
3A October 2000	 Zenith 1 (Z1) Truss, PMA 3	Space Shuttle STS-92	

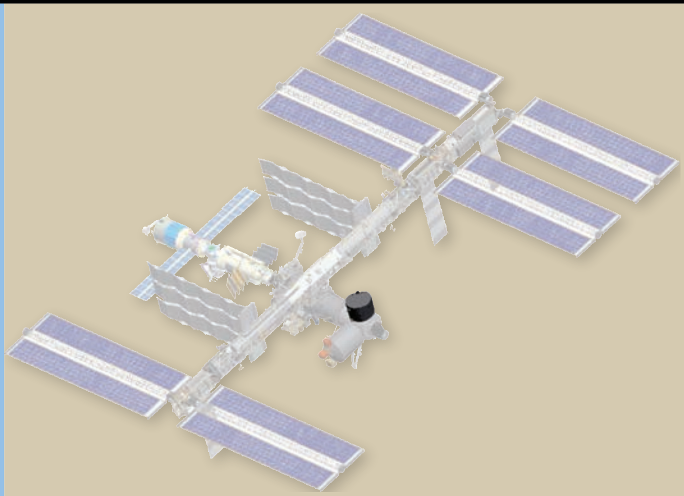
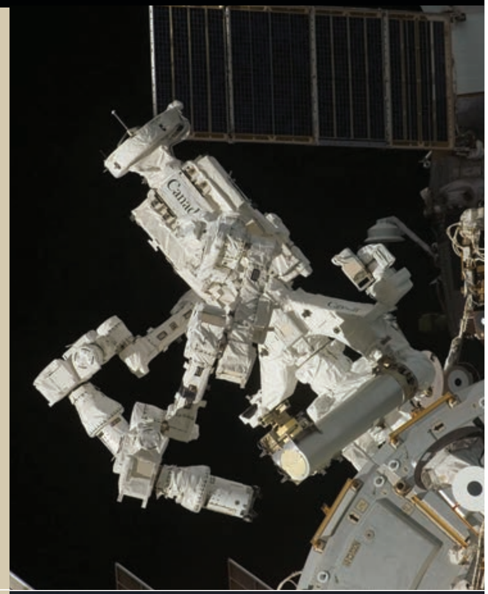
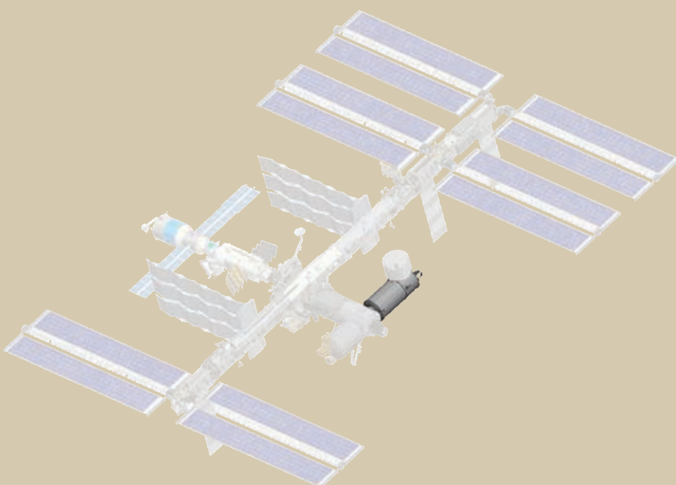
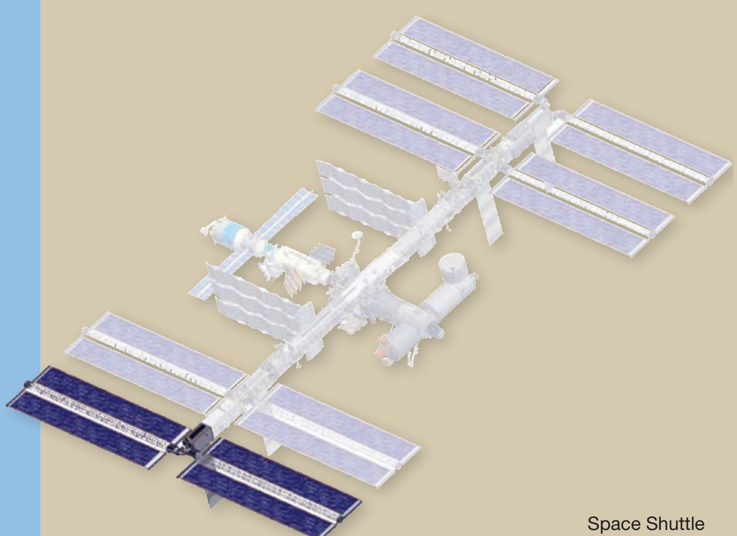
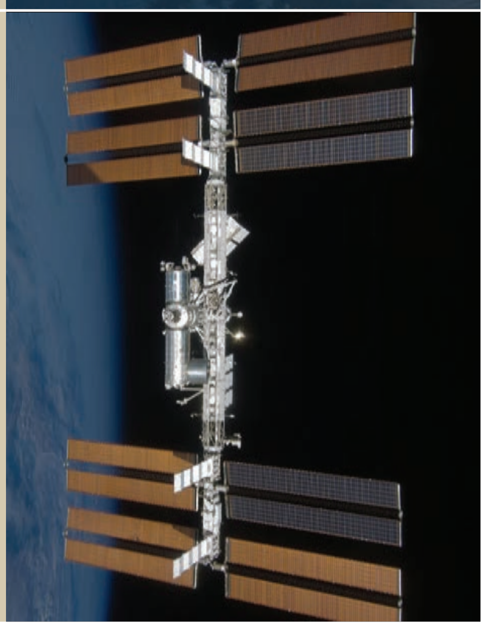
Stage/ Date	Element Added	Launch Vehicle	ISS Picture
4A December 2000	 Port 6 (P6) Truss	Space Shuttle STS-97	
5A February 2001	 U.S. Laboratory (Lab)	Space Shuttle STS-98	
5A.1 March 2001	 External Stowage Platform (ESP) 1	Space Shuttle STS-98	
6A April 2001	 Space Station Remote Manipulator System (SSRMS)	Space Shuttle STS-100	

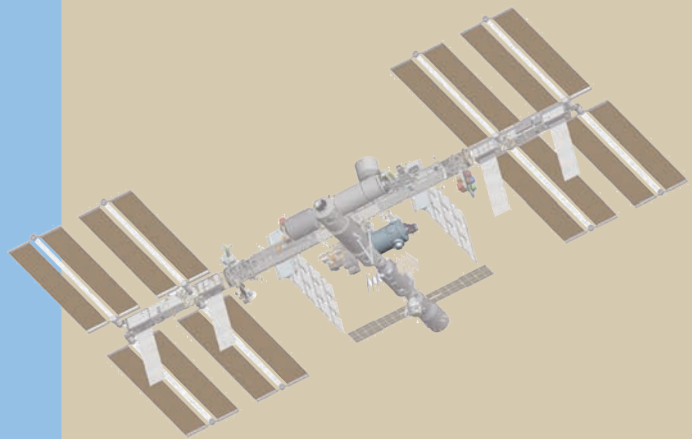
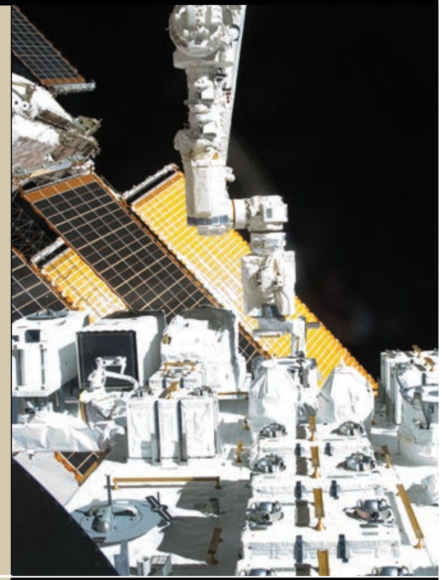
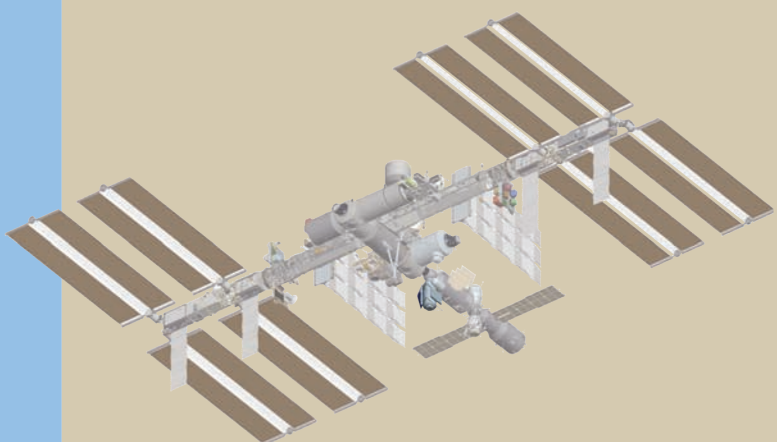
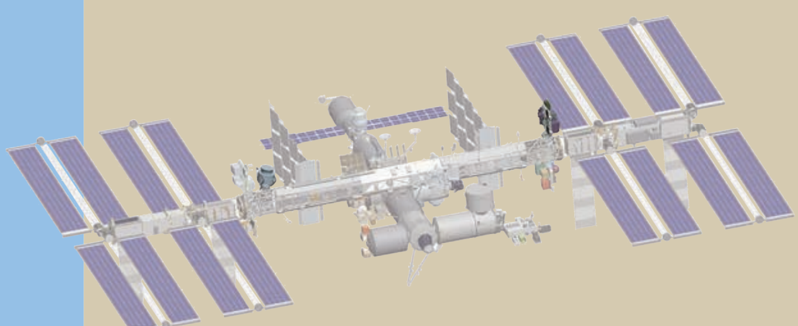
Stage/ Date	Element Added	Launch Vehicle	ISS Picture
7A July 2001	 U.S. Airlock	Space Shuttle STS-104	
4R September 2001	 Russian Docking Compartment (DC) and Airlock	Soyuz	
8A April 2002	 Starboard Zero (S0) Truss and Mobile Transporter (MT)	Space Shuttle STS-110	
UF-2 June 2002	 Mobile Base System	Space Shuttle STS-111	

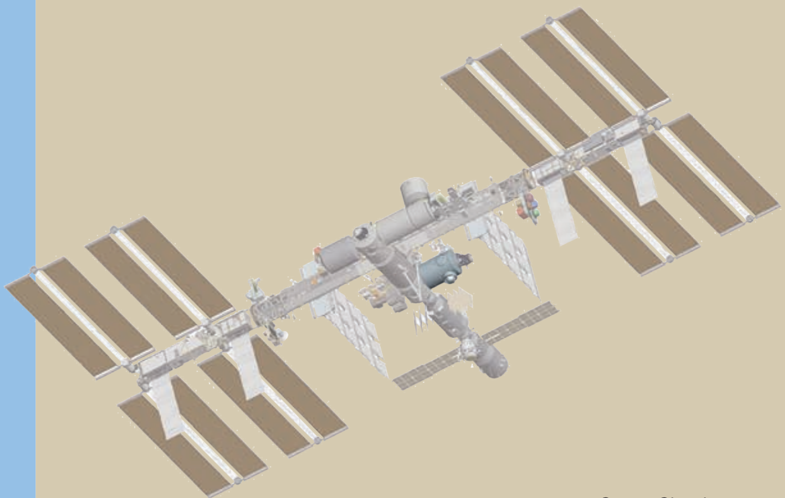
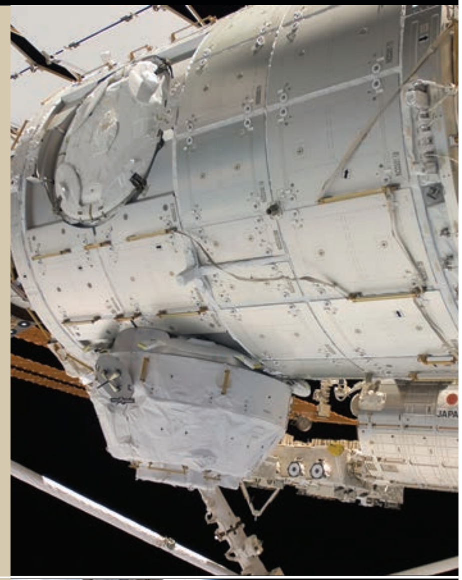
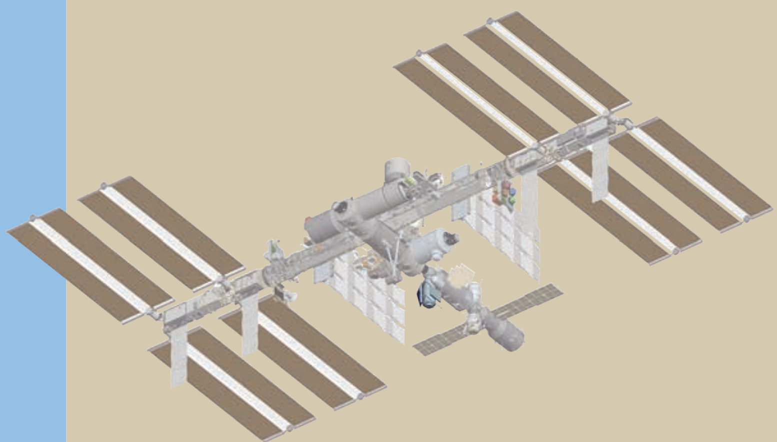
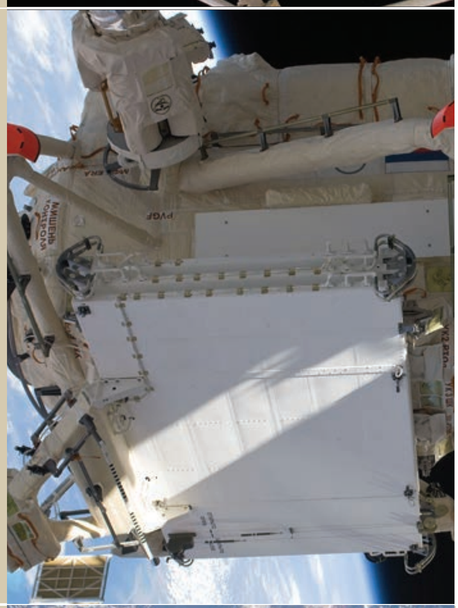
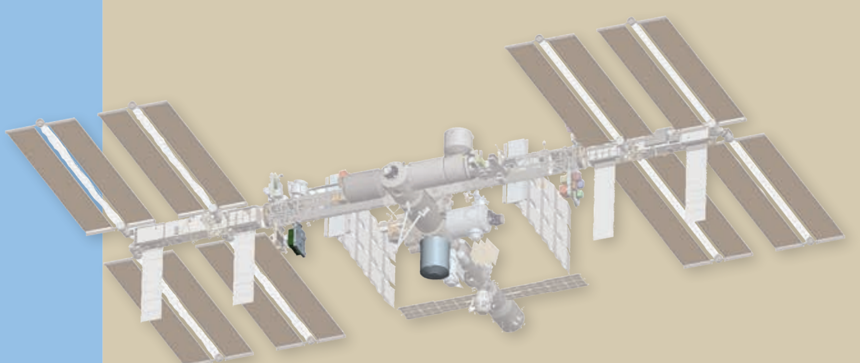
Stage/ Date	Element Added	Launch Vehicle	ISS Picture
9A October 2002	 S1 Truss and Crew Equipment Translation Aid (CETA) Cart	Space Shuttle STS-112	
11A November 2002	 P1 Truss and CETA Cart	Space Shuttle STS-113	
LF1 July 2005	 ESP-2	Space Shuttle STS-114	

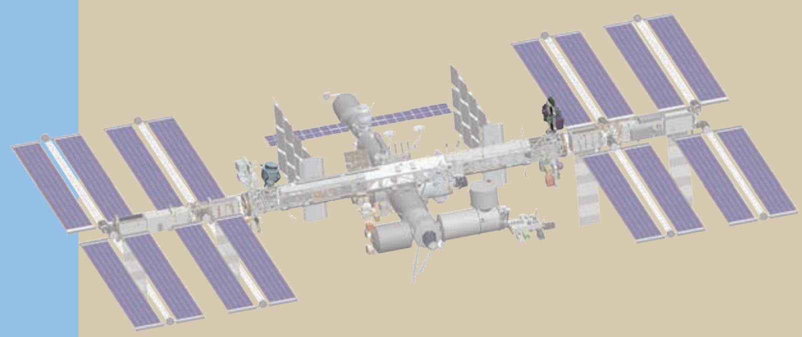
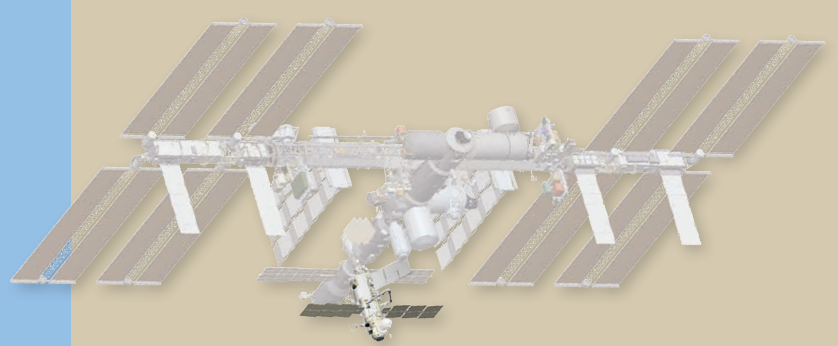
Stage/ Date	Element Added	Launch Vehicle	ISS Picture
12A September 2006	 P3/P4 Truss	Space Shuttle STS-115	
12A.1 December 2006	 P5 Truss, retracting P6 arrays	Space Shuttle STS-116	
13A June 2007	 S3/S4 Truss	Space Shuttle STS-117	

Stage/ Date	Element Added	Launch Vehicle	ISS Picture
13A.1 August 2007	 S5 Truss and ESP-3	Space Shuttle STS-118	
10A October 2007	 Node 2, P6 relocated	Space Shuttle STS-120	
1E February 2008	 ESA Columbus Module	Space Shuttle STS-122	

Stage/ Date	Element Added	Launch Vehicle	ISS Picture
1J/A March 2008	 Japanese Experiment Module Experiment Logistics Module Pressurized Section (JEM-ELM-PS) and Canadian Special Purpose Dexterous Manipulator (Dextre)	Space Shuttle STS-123	
1J June 2008	 JEM Pressurized Module (PM)	Space Shuttle STS-124	
15A March 2009	 S6 Truss	Space Shuttle STS-119	

Stage/ Date	Element Added	Launch Vehicle	ISS Picture
2J/A July 2009	 JEM Exposed Facility (JEM-EF)	Space Shuttle STS-127	
5R November 2009	 Russian Mini-Research Module 2	Soyuz	
ULF3 November 2009	 ExPRESS Logistics Carriers (ELC) 1, 2	Space Shuttle STS-129	

Stage/ Date	Element Added	Launch Vehicle	ISS Picture
20A February 2010	 Node 3 and Cupola	Space Shuttle STS-130	
ULF4 May 2010	 Russian Mini-Research Module 1 (MRM-1)	Space Shuttle STS-132	
ULF5	 Permanent Multipurpose Module (PMM) and ELC-4	Space Shuttle STS-133	

Stage/ Date	Element Added		Launch Vehicle	ISS Picture
ULF6	Alpha Magnetic Spectrometer (AMS) and ELC-3		Space Shuttle STS-134	
3R	Russian Multipurpose Laboratory Module and European Robotic Arm (ERA)		Proton	

Missions

High-performing personnel are key to International Space Station (ISS) mission success. International crewmembers and ground controllers who support assembly, logistics, and long-duration missions have highly specialized skills and training. They also utilize procedures and tools developed especially for the ISS.

The experience gained from the ISS program has improved the interaction between the flight crews and ground-team members and has made missions safer and more effective. Moreover, working with teams from many countries and cultures on the ground and in space has provided (and continues to provide) innovative solutions to critical operational challenges.

ISS Expeditions and Crews

1

Start on November 2, 2001

End on March 18, 2001

136 days on ISS

- William Shepherd
- Yuri Gidzenko
- Sergei Krikalev

2

Start March 10, 2001

End August 20, 2001

163 days on ISS

- Yuri Usachev
- Jim Voss
- Susan Helms

3

Begin August 12, 2001

End December 15, 2001

125 days on ISS

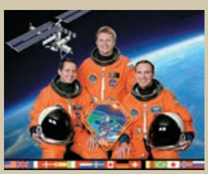
- Frank Culbertson
- Vladimir Dezhurov
- Mikhail Tyurin

4

Start December 7, 2001

End June 15, 2001

190 days on ISS



- Yury Onufrienko
- Carl Walz
- Daniel Bursch

5

Start June 7, 2002

December 2, 2002

178 days on ISS

- Valery Korzun
- Sergei Treschev
- Peggy Whitson

6

Start November 25, 2002

End May 3, 2003

159 days on ISS

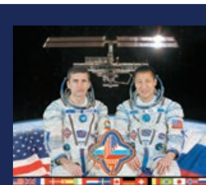
- Kenneth Bowersox
- Nikolai Budarin
- Donald Pettit

7

Start April 28, 2003

End October 27, 2003

183 days on ISS



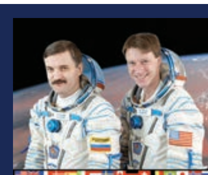
- Yuri Malenchenko
- Edward Lu

8

Start October 20, 2003

End April 29, 2004

193 days on ISS



- Michael Foale
- Alexander Kaleri

9

Start April 21, 2004

End October 23, 2004

186 days on ISS

- Gennady Padalka
- E. Michael Fincke

10

October 14, 2004

April 24, 2005

190 days on ISS

- Leroy Chiao
- Salizhan Sharipov

11

Start April 17, 2005
End October 10, 2005
177 days on ISS

- Sergei Krikalev
- John Phillips

12

Start October 3, 2005
End April 8, 2006
188 days on ISS

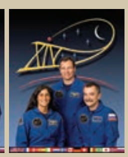
- William S. McArthur
- Valery Tokarev

13

Start April 1, 2006
End September 28, 2006
181 days on ISS

- Pavel Vinogradov
- Jeffrey Williams
- Thomas Reiter

14



Start September 18, 2006
End April 21, 2007
205 days on ISS

- Michael E. Lopez-Alegria
- Mikhail Tyurin
- Thomas Reiter
- Sunita L. Williams

15

Start April 7, 2007
End October 21, 2007
197 days on ISS

- Fyodoro Yurchikhin
- Oleg Kotov
- Sunita Williams
- Clayton Anderson

16

Start October 10, 2007
End April 19, 2008
192 days on ISS

- Peggy Whitson
- Yuri Malenchenko
- Clayton Anderson
- Daniel Tani
- Léopold Eyharts
- Garrett Reisman

17

Start April 8, 2008
End October, 23 2008
198 days on ISS

- Sergey Vokov
- Oleg Kononenko
- Garrett Reisman
- Gregory Chamitoff

18

Start October 14, 2008
End April 8, 2009
178 days on ISS

- Michael Finke
- Yuri Lonchakov
- Gregory Chamitoff
- Sandra Magnus
- Kochi Wakata

19

Start April 8, 2009
End May 29, 2009
62 days on ISS

- Gennady Padalka
- Michael Barratt
- Kochi Wakata

20

Start May 29, 2009
End October 11, 2009
135 days on ISS

- Gennady Padalka
- Michael Barratt
- Kochi Wakata
- Timothy Kopra
- Nicole Stott
- Frank De Winne
- Roman Romanenko
- Robert Thirsk

21

Start October 11, 2009
End December 1, 2009
51 days on ISS

- Frank De Winne
- Roman Romanenko
- Robert Thirsk
- Jeffrey Williams
- Maksim Surayev
- Nicole Stott

22

Start December 1, 2009
End March 18, 2010
107 days on ISS

- Jeffrey Williams
- Maksim Surayev
- Oleg Kotov
- Soichi Noguchi
- Timothy Creamer

23

Start December 7, 2001
End June 15, 2001
190 days on ISS

- Oleg Kotov
- Soichi Noguchi
- Timothy Creamer
- Aleksandr Skvortsov
- Mikhail Korniyenko
- Tracy Caldwell Dyson

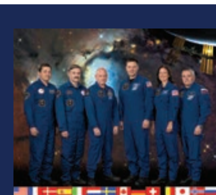
24

Start November 25, 2002
End May 3, 2003
176 days on ISS

- Aleksandr Skvortsov
- Mikhail Korniyenko
- Tracy Caldwell Dyson
- Fyodor Yurchikhin
- Shannon Walker
- Douglas Wheelock

25

Start September 25, 2010
End November 26, 2010
159 days on ISS



- Douglas H. Wheelock
- Shannon Walker
- Fyodor Yurchikhin
- Scott J. Kelly
- Aleksandr Kaleri
- Oleg Skripochka

26

Start November 26, 2010
End March 16, 2011
160 days on ISS

- Scott J. Kelly
- Aleksandr Kaleri
- Oleg Skripochka
- Dimitri Kondratyev
- Catherine G. Coleman
- Paolo Nespoli

27

Start March 16, 2011
End May 23, 2011
164 days on ISS

- Dimitri Kondratyev
- Catherine G. Coleman
- Paolo Nespoli
- Andrei Borisenko
- Aleksandr Samokutyayev
- Ronald J. Garan

28

Start May 23, 2011
End September 16, 2011
167 days on ISS

- Andrei Borisenko
- Aleksandr Samokutyayev
- Ronald J. Garan
- Michael E. Fossum
- Sergey Volkov
- Satoshi Furukawa

29

Start September 16, 2011
End November 16, 2011
165 days on ISS

- Michael E. Fossum
- Sergey Volkov
- Satoshi Furukawa
- Daniel C. Burbank
- Anton Shkaplerov
- Anatoli Ivanishin

30

Start November 16, 2011
End April 27, 2012
192 days on ISS

- Daniel C. Burbank
- Anton Shkaplerov
- Anatoli Ivanishin
- Oleg Kononenko
- Donald R. Pettit
- André Kuipers

31

Start April 27, 2012
End July 1, 2012
124 days on ISS

- Oleg Kononenko
- Donald R. Pettit
- André Kuipers
- Gennady Padalka
- Sergei Revin
- Joseph M. Acaba

32

Start July 1, 2012
End September 17, 2012
126 days on ISS

- Gennady Padalka
- Sergei Revin
- Joseph M. Acaba
- Sunita L. Williams
- Yuri Malenchenko
- Akihiko Hoshide

33

Start September 17, 2012
End November 18, 2012
143 days on ISS

- Sunita L. Williams
- Yuri Malenchenko
- Akihiko Hoshide
- Kevin A. Ford
- Oleg Novitskiy
- Evgeny Tarelkin

34

Start November 18, 2012
End March 15, 2013
145 days on ISS

- Kevin A. Ford
- Oleg Novitskiy
- Evgeny Tarelkin
- Chris Hadfield
- Roman Romanenko
- Thomas H. Marshburn

35

Start March 15, 2013
End May 13, 2013
166 days on ISS

- Chris Hadfield
- Roman Romanenko
- Thomas H. Marshburn
- Pavel Vinogradov
- Aleksandr Misurkin
- Christopher J. Cassidy

36

Start May 13, 2013
End September 11, 2013
166 days on ISS

- Pavel Vinogradov
- Aleksandr Misurkin
- Christopher J. Cassidy
- Fyodor Yurchikhin
- Karen L. Nyberg
- Luca Parmitano

37

Start September 11, 2013
End November 10, 2013
166 days on ISS

- Fyodor Yurchikhin
- Karen L. Nyberg
- Luca Parmitano
- Oleg Kotov
- Sergey Ryazansky
- Michael S. Hopkins

38

Start November 10, 2013
End March 11, 2014
188 days on ISS

- Oleg Kotov
- Sergey Ryazansky
- Michael S. Hopkins
- Koichi Wakata
- Mikhail Tyurin
- Richard A. Mastracchio

39

Start March 11, 2014
End May 13, 2014
169 days on ISS

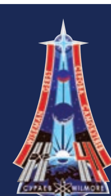
- Koichi Wakata
- Mikhail Tyurin
- Richard A. Mastracchio
- Aleksandr Skvortsov
- Oleg Artemyev
- Steven R. Swanson

40

Start May 13, 2014
End September 11, 2014
165 days on ISS

- Steven R. Swanson
- Aleksandr Skvortsov
- Oleg Artemyev
- Gregory R. Wiseman
- Maksim Surayev
- Alexander Gerst

41

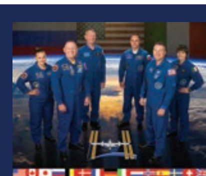


Start September 11, 2014
End November 10, 2014
167 days on ISS

- Maksim Surayev
- Gregory R. Wiseman
- Alexander Gerst
- Aleksandr Samokutyayev
- Yelena Serova
- Barry E. Wilmore

42

Start November 10, 2014
End March 12, 2015
169 days on ISS



- Barry E. Wilmore
- Aleksandr Samokutyayev
- Yelena Serova
- Anton Shkaplerov
- Samantha Cristoforetti
- Terry W. Virts

43

Start March 12, 2015
End May 13, 2015

- Anton Shkaplerov
- Samantha Cristoforetti
- Terry W. Virts
- Scott Kelly
- Mikhail Kornienko
- Genady Padalka

44

Start May 13, 2015
End September 11, 2015

- Scott Kelly
- Mikhail Kornienko
- Genady Padalka
- Kjell Lindgren
- Oleg Kononenko
- Kimiya Yui

For information on current mission, visit http://www.nasa.gov/mission_pages/station/expeditions/index.html


United States

STS Missions and Crews

Space Shuttle Missions to the ISS

ISS Flight 2A
STS-88 *Endeavour*

Launched December 4, 1998
Landed December 15, 1998
12 days

- Robert D. Cabana
- Frederick W. Sturckow
- Nancy J. Currie
- Jerry L. Ross
- James H. Newman
- Sergei Krikalev

ISS Flight 3A
STS-92 *Discovery*

Launched October 11, 2000
Landed October 24, 2000
13 days

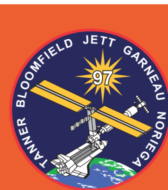
- Brian Duffy
- Pamela A. Melroy
- Leroy Chiao
- William S. McArthur
- Peter J. K. Wisoff
- Michael E. Lopez-Alegria
- Koichi Wakata

ISS Flight 2A.1
STS-96 *Discovery*

Launched May 27, 1999
Landed June 6, 1999
10 days

- Kent V. Rominger
- Rick D. Husband
- Tamara E. Jernigan
- Ellen L. Ochoa
- Daniel T. Barry
- Julie Payette
- Valery Tokarev

ISS Flight 4A
STS-97 *Endeavour*



Launched November 30, 2000
Landed December 11, 2000
11 days

- Brent W. Jett
- Michael J. Bloomfield
- Joseph R. Tanner
- Carlos I. Noriega
- Marc Garneau

ISS Flight 2A.2a
STS-101 *Atlantis*

Launched May 19, 2000
Landed May 29, 2000
10 days

- James D. Halsell
- Scott J. Horowitz
- Mary E. Weber
- Jeffrey N. Williams
- James S. Voss
- Susan J. Helms
- Yury Usachev

ISS Flight 5A
STS-98 *Atlantis*

Launched February 7, 2001
Landed February 20, 2001
13 days

- Kenneth D. Cockrell
- Mark L. Polansky
- Robert L. Curbeam
- Marsha S. Ivins
- Thomas D. Jones

ISS Flight 2A.2b
STS-106 *Atlantis*

Launched September 8, 2000
Landed September 20, 2000
12 days

- Terrence W. Wilcutt
- Scott D. Altman
- Edward T. Lu
- Richard A. Mastracchio
- Daniel C. Burbank
- Yuri Malenchenko
- Boris Morukov

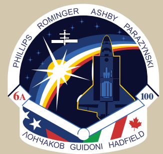
ISS Flight 5A.1
STS-102 *Discovery*

Launched March 8, 2001
Landed March 21, 2001
12 days

- James D. Wetherbee
- James M. Kelly
- Paul W. Richards
- Andrew S. W. Thomas
- Yury Usachev
- James S. Voss
- Susan J. Helms

ISS Flight 6A

STS-100
Endeavour



Launched
April 19, 2001

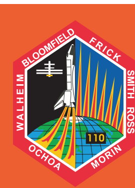
Landed
May 1, 2001

12 days

- Kent V. Rominger
- Jeffrey S. Ashby
- John L. Phillips
- Scott E. Parazynski
- Chris A. Hadfield
- Umberto Guidoni
- Yuri Lonchakov

ISS Flight 8A

STS-110
Atlantis



Launched
April 8, 2002

Landed
April 19, 2002

11 days

- Michael J. Bloomfield
- Stephen N. Frick
- Jerry L. Ross
- Steven L. Smith
- Ellen L. Ochoa
- Lee M. E. Morin
- Rex J. Walheim

ISS Flight 7A

STS-104
Atlantis

Launched
July 12, 2001

Landed
July 24, 2001

13 days

- Steven W. Lindsey
- Charles O. Hobaugh
- Michael L. Gernhardt
- Janet L. Kavandi
- James F. Reilly

ISS Flight UF-2

STS-111
Endeavour

Launched
June 5, 2002

Landed
June 19, 2002

11 days

- Kenneth D. Cockrell
- Paul S. Lockhart
- Franklin R. Chang-Diaz
- Philippe Perrin
- Valery Korzun
- Sergei Treshchev
- Peggy A. Whitson

ISS Flight 7A.1

STS-105
Discovery

Launched
August 10, 2001

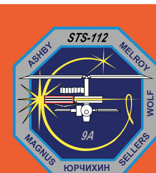
Landed
August 22, 2001

10 days

- Scott J. Horowitz
- Frederick W. Sturckow
- Daniel T. Barry
- Patrick G. Forrester
- Frank L. Culbertson
- Mikhail Tyurin
- Vladimir Dezhurov

ISS Flight 9A

STS-112
Atlantis



Launched
October 7, 2002

Landed
October 18, 2002

11 days

- Jeffrey S. Ashby
- Pamela A. Melroy
- David A. Wolf
- Sandra H. Magnus
- Piers J. Sellers
- Fyodor Yurchikhin

ISS Flight UF-1

STS-108
Endeavour

Launched
December 5, 2001

Landed
December 17, 2001

12 days

- Dominic L. Pudwill Gorie
- Mark E. Kelly
- Linda M. Godwin
- Daniel M. Tani
- Yuri Onufrienko
- Carl E. Walz
- Daniel W. Bursch

ISS Flight 11A

STS-113
Endeavour

Launched
November 23, 2002

Landed
December 7, 2002

14 days

- James D. Wetherbee
- Paul S. Lockhart
- Michael E. Lopez-Alegria
- John B. Herrington
- Kenneth D. Bowersox
- Donald R. Pettit
- Nikolai Budarin

ISS Flight
LF1
STS-114
Discovery

Launched
July 26, 2005

Landed
August 9, 2005

14 days

- Eileen M. Collins
- James M. Kelly
- Stephen K. Robinson
- Andrew S. W. Thomas
- Wendy B. Lawrence
- Charles J. Camarda
- Soichi Noguchi

ISS Flight
13A
STS-117
Atlantis

Launched
June 8, 2007

Landed
June 22, 2007

13 days

- Frederick W. Sturckow
- Lee J. Archambault
- Patrick G. Forrester
- Steven R. Swanson
- John D. Olivas
- James F. Reilly
- Clayton C. Anderson

ISS Flight
ULF1.1
STS-121
Discovery

Launched
July 4, 2006

Landed
July 17, 2006

13 days

- Steven W. Lindsey
- Mark E. Kelly
- Michael E. Fossum
- Lisa M. Nowak
- Stephanie D. Wilson
- Piers J. Sellers
- Thomas Reiter

ISS Flight
13A.1
STS-118
Endeavour

Launched
August 8, 2007

Landed
August 21, 2007

13 days

- Scott J. Kelly
- Charles O. Hobaugh
- Tracy E. Caldwell Dyson
- Richard A. Mastracchio
- Barbara R. Morgan
- Benjamin A. Drew
- Dafydd R. Williams

ISS Flight
12A
STS-115
Atlantis

Launched
September 9, 2006

Landed
September 21, 2006

12 days

- Brent W. Jett
- Christopher J. Ferguson
- Daniel C. Burbank
- Heidemarie M. Stefanyshyn-Piper
- Joseph R. Tanner
- Steven G. MacLean

ISS Flight
10A
STS-120
Discovery

Launched
October 23, 2007

Landed
Novemeber 7, 2007

15 days

- Pamela A. Melroy
- George D. Zamka
- Scott E. Parazynski
- Stephanie D. Wilson
- Douglas H. Wheelock
- Paolo Nespoli
- Daniel M. Tani

ISS Flight
12A.1
STS-116
Discovery

Launched
December 9, 2009

Landed
December 22, 2009

13 days

- Mark L. Polansky
- William A. Oefelein
- Nicholas J. M. Patrick
- Robert L. Curbeam
- Joan E. Higginbotham
- Christer Fuglesang
- Sunita L. Williams

ISS Flight
1E
STS-122
Atlantis

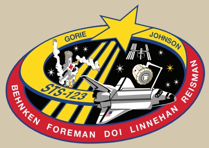
Launched
February 7, 2008

Landed
February 20, 2008

13 days

- Stephen N. Frick
- Alan G. Poindexter
- Leland D. Melvin
- Rex J. Walheim
- Stanley G. Love
- Hans Schlegel
- Léopold Eyharts

ISS Flight
1J/A
STS-123
Endeavour



Launched
March 11, 2008

Landed
March 26, 2008

15 days

- Dominic L. Pudwill Gorie
- Gregory H. Johnson
- Robert L. Behnken
- Michael J. Foreman
- Richard M. Linnehan
- Takao Doi
- Garrett E. Reisman

ISS Flight
2J/A
STS-127
Endeavour

Launched
July 15, 2009

Landed
July 31, 2009

16 days

- Mark L. Polansky
- Douglas G. Hurley
- Christopher J. Cassidy
- Thomas H. Marshburn
- David A. Wolf
- Julie Payette
- Timothy L. Kopra

ISS Flight
1J
STS-124
Discovery

Launched
May 31, 2008

Landed
June 14, 2008

14 days

- Mark E. Kelly
- Kenneth T. Ham
- Karen L. Nyberg
- Ronald J. Garan
- Michael E. Fossum
- Akihiko Hoshide
- Gregory E. Chamitoff

ISS Flight
17A
STS-128
Discovery

Launched
August 28, 2009

Landed
September 11, 2009

14 days

- Frederick W. Sturckow
- Kevin A. Ford
- Patrick G. Forrester
- Jose M. Hernández
- John D. Olivas
- Christer Fuglesang
- Nicole P. Stott

ISS Flight
ULF2
STS-126
Endeavour

Launched
November 14, 2008

Landed
Novemeber 30, 2008

16 days

- Christopher J. Ferguson
- Eric A. Boe
- Donald R. Pettit
- Stephen G. Bowen
- Heidemarie M. Stefanyshyn-Piper
- Robert S. Kimbrough
- Sandra H. Magnus

ISS Flight
ULF3
STS-129
Atlantis

Launched
November 16, 2009

Landed
November 27, 2009

11 days

- Charles O. Hobaugh
- Barry E. Wilmore
- Michael J. Foreman
- Randolph J. Bresnik
- Leland D. Melvin
- Robert L. Satcher

ISS Flight
15A
STS-119
Discovery

Launched
March 15, 2009

Landed
March 28, 2009

13 days

- Lee J. Archambault
- Dominic A. Antonelli
- Joseph M. Acaba
- Steven R. Swanson
- Richard R. Arnold
- John L. Phillips
- Koichi Wakata

ISS Flight
20A
STS-130
Endeavour

Launched
February 8, 2010

Landed
February 21, 2010

13 days

- George D. Zamka
- Terry W. Virts
- Kathryn P. Hire
- Stephen K. Robinson
- Nicholas J. M. Patrick
- Robert L. Behnken

ISS Flight 19A

STS-131
Discovery

Launched
April 5, 2010

Landed
April 20, 2010

15 days

- Alan G. Poindexter
- James P. Dutton
- Richard A. Mastracchio
- Clayton C. Anderson
- Dorothy M. Metcalf-Lindenburger
- Stephanie D. Wilson
- Naoko Yamazaki

ISS Flight ULF7

STS-135
Atlantis

Launched
July 8, 2011

Landed
July 21, 2011

13 days

- Christopher J. Ferguson
- Douglas G. Hurley
- Sandra H. Magnus
- Rex J. Walheim

ISS Flight ULF4

STS-132
Atlantis

Launched
May 14, 2010

Landed
May 26, 2010

11 days

- Kenneth T. Ham
- Dominic A. Antonelli
- Stephen G. Bowen
- Michael T. Good
- Piers J. Sellers
- Garrett E. Reisman

ISS Flight ULF5

STS-133
Discovery

Launched
February 24, 2011

Landed
March 9, 2011

13 days

- Steven W. Lindsey
- Eric A. Boe
- Benjamin A. Drew
- Michael R. Barratt
- Stephen G. Bowen
- Nicole P. Stott

ISS Flight ULF6

STS-134
Endeavour

Launched
May 16, 2011

Landed
June 1, 2011

16 days

- Mark E. Kelly
- Gregory H. Johnson
- Michael Fincke
- Gregory E. Chamitoff
- Andrew J. Feustel
- Roberto Vittori

Soyuz ISS Missions

ISS Flight
2R
Soyuz TM-31

Launched
October 31, 2000
Undocked
May 6, 2001
186 days

- Yuri Gidzenko
- Sergei Krikalev
- William M. Shepherd

ISS Flight
6S
Soyuz TMA-2

Launched
April 26, 2003
Undocked
October 27, 2003
185 days

- Yuri Malenchenko
- Edward T. Lu

ISS Flight
2S
Soyuz TM-32

Launched
April 28, 2001
Undocked
October 31, 2001
186 days

- Talgat Musabayev
- Yuri Baturin
- Dennis A. Tito (SFP)

ISS Flight
7S
Soyuz TMA-3

Launched
October 18, 2003
Undocked
April 29, 2004
192 days

- Alexander Kaleri
- Michael Foale
- Pedro Duque

ISS Flight
3S
Soyuz TM-33

Launched
October 21, 2001
Undocked
May 5, 2002
196 days

- Viktor Afanasyev
- Konstantin Kozeyev
- Claudie Haigneré

ISS Flight
8S
Soyuz TMA-4

Launched
April 19, 2004
Undocked
October 23, 2004
187 days

- Gennady Padalka
- Michael Fincke
- André Kuipers

ISS Flight
4S
Soyuz TM-34

Launched
April 25, 2002
Undocked
November 9, 2002
198 days

- Yuri Gidzenko
- Roberto Vittori
- Mark Shuttleworth (SFP)

ISS Flight
9S
Soyuz TMA-5

Launched
October 14, 2004
Undocked
April 24, 2005
193 days

- Salizhan Sharipov
- Leroy Chiao
- Yuri Shargin

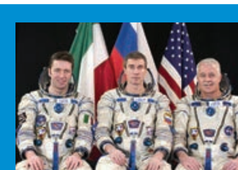
ISS Flight
5S
Soyuz TMA-1

Launched
October 20, 2002
Undocked
May 3, 2003
186 days

- Sergei Zalyotin
- Yuri Lonchakov
- Frank De Winne

ISS Flight
10S
Soyuz TMA-6

Launched
April 15, 2005
Undocked
October 10, 2005
180 days



- Sergei Krikalev
- John L. Phillips
- Roberto Vittori

ISS Flight 11S
Soyuz TMA-7

Launched
October 1, 2005

Undocked
April 8, 2006

190 days

- Valery Tokarev
- William S. McArthur
- Gregory H. Olsen (SFP)

ISS Flight 16S
Soyuz TMA-12

Launched
April 8, 2008

Undocked
October 24, 2008

199 days

- Sergei Volkov
- Oleg Kononenko
- Yi So Yeon (SFP)

ISS Flight 12S
Soyuz TMA-8

Launched
March 30, 2006

Undocked
September 28, 2006

182 days

- Pavel Vinogradov
- Jeffrey N. Williams
- Marcos Pontes (SFP)

ISS Flight 17S
Soyuz TMA-13

Launched
October 12, 2008

Undocked
April 8, 2009

178 days

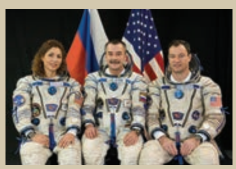
- Yuri Lonchakov
- Michael Fincke
- Richard A. Garriott (SFP)

ISS Flight 13S
Soyuz TMA-9

Launched
September 18, 2006

Undocked
April 21, 2007

215 days



- Mikhail Tyurin
- Michael E. Lopez-Alegria
- / Anousheh Ansari (SFP)

ISS Flight 18S
Soyuz TMA-14

Launched
March 26, 2009

Undocked
October 11, 2009

199 days

- Gennady Padalka
- Michael R. Barratt
- / Charles Simonyi (SFP)

ISS Flight 14S
Soyuz TMA-10

Launched
April 7, 2007

Undocked
October 21, 2007

196 days

- Oleg Kotov
- Fyodor Yurchikhin
- / Charles Simonyi (SFP)

ISS Flight 19S
Soyuz TMA-15

Launched
May 27, 2009

Undocked
December 1, 2009

188 days

- Roman Romanenko
- Frank de Winne
- Robert B. Thirsk

ISS Flight 15S
Soyuz TMA-11

Launched
October 11, 2007

Undocked
April 19, 2008

191 days

- Yuri Malenchenko
- Peggy A. Whitson
- Sheikh Muszaphar Shukor (SFP)

ISS Flight 20S
Soyuz TMA-16

Launched
September 30, 2009

Undocked
March 18, 2010

169 days

- Maksim Surayev
- Jeffrey N. Williams
- Guy Laliberté (SFP)

ISS Flight
21S
Soyuz TMA-17

Launched
December 20, 2009

Undocked
June 2, 2010

164 days

- Oleg Kotov
- Timothy J. Creamer
- Soichi Noguchi

ISS Flight
22S
Soyuz TMA-18

Launched
April 2, 2010

Undocked
September 25, 2010

176 days

- Aleksandr Skvortsov
- Mikhail Korniyenko
- Tracy E. Caldwell Dyson

ISS Flight
23S
Soyuz TMA-19

Launched
June 15, 2010

Undocked
Novemeber 26, 2010

163 days

- Fyodor Yurchikhin
- Douglas H. Wheelock
- Shannon Walker

ISS Flight
24S
Soyuz TMA-01M

Launched
October 7, 2010

Undocked
March 16, 2011

159 Days

- Alexander Kaleri
- Oleg Skripochka
- Scott J. Kelly

ISS Flight
25S
Soyuz TMA-20

Launched
December 15, 2010

Undocked
May 23, 2011

159 Days

- Dimitri Kondratyev
- Catherine G. Coleman
- Paolo Nespoli

ISS Flight
26S
Soyuz TMA-21

Launched
April 4, 2011

Undocked
September 16, 2011

164 Days

- Aleksandr Samokutyayev
- Andrei Borisenko
- Ronald J. Garan

ISS Flight
27S
Soyuz TMA-02M

Launched
October 12, 2008

Undocked
April 8, 2009

166 Days

- Sergey Volkov
- Michael E. Fossum
- Satoshi Furukawa

ISS Flight
28S
Soyuz TMA-22

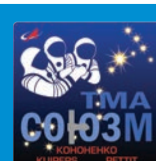
Launched
November 14, 2011

Undocked
April 27, 2012

165 Days

- Anton Shkaplerov
- Anatoli Ivanishin
- Daniel C. Burbank

ISS Flight
29S
Soyuz TMA-03M



Launched
December 21, 2011

Undocked
July 1, 2012

192 Days

- Oleg Kononenko
- Donald R. Pettit
- André Kuipers

ISS Flight
30S
Soyuz TMA-04M

Launched
May 15, 2012

Undocked
September 17, 2012

124 Days

- Gennady Padalka
- Sergei Revin
- Joseph M. Acaba

ISS Flight
31S
Soyuz
TMA-05M

Launched
July 15, 2012
Undocked
November 18, 2012
126 Days

- Yuri Malenchenko
- Sunita L. Williams
- Akihiko Hoshide

ISS Flight
36S
Soyuz
TMA-10M

Launched
September 25, 2013
Undocked
March 11, 2014
166 Days

- Oleg Kotov
- Sergey Ryazansky
- Michael S. Hopkins

ISS Flight
32S
Soyuz
TMA-06M

Launched
October 23, 2012
Undocked
March 15, 2013
143 Days

- Oleg Novitskiy
- Evgeny Tarelkin
- Kevin A. Ford

ISS Flight
37S
Soyuz
TMA-11M

Launched
November 7, 2013
Undocked
May 13, 2014
187 Days

- Mikhail Tyurin
- Richard A. Mastracchio
- Koichi Wakata

ISS Flight
33S
Soyuz
TMA-07M

Launched
December 19, 2012
Undocked
May 13, 2013
145 Days

- Roman Romanenko
- Thomas H. Marshburn
- Chris A. Hadfield

ISS Flight
38S
Soyuz
TMA-12M

Launched
March 25, 2014
Undocked
September 11, 2014
169 Days

- Aleksandr Skvortsov
- Oleg Artemyev
- Steven R. Swanson

ISS Flight
34S
Soyuz
TMA-08M

Launched
March 28, 2013
Undocked
September 11, 2013
166 Days

- Pavel Vinogradov
- Aleksandr Misurkin
- Christopher J. Cassidy

ISS Flight
39S
Soyuz
TMA-13M

Launched
May 28, 2014
Undocked
November 10, 2014
165 Days

- Maksim Surayev
- Gregory R. Wiseman
- Alexander Gerst

ISS Flight
35S
Soyuz
TMA-09M

Launched
May 28, 2013
Undocked
November 10, 2013
166 Days

- Fyodor Yurchikhin
- Karen L. Nyberg
- Luca Parmitano

ISS Flight
40S
Soyuz
TMA-14M

Launched
September 25, 2014
Undocked
May 12, 2015
167 Days

- Aleksandr Samokutyayev
- Yelena Serova
- Barry E. Wilmore

ISS Flight

41S

Soyuz TMA-15M

Launched
November 23, 2014

Undocked
TBD

- Anton Shkaplerov
- Samantha Cristoforetti
- Terry W. Virts

ISS Flight

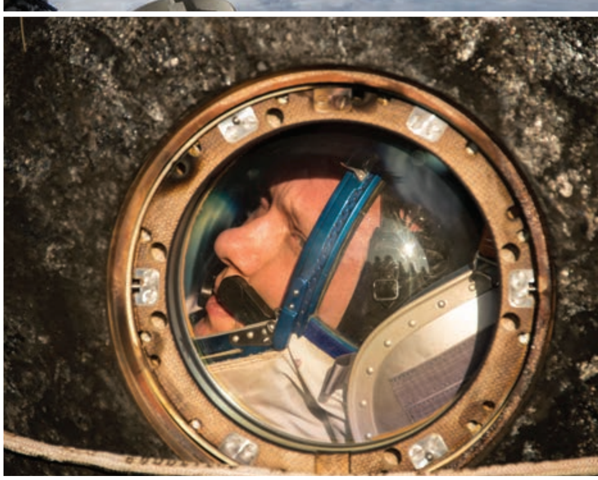
42S

Soyuz TMA-16M

Launched
March 27, 2015

Undocked
TBD

- Gennady Padalka
- Mikhail Korniyenko
- Scott J. Kelly

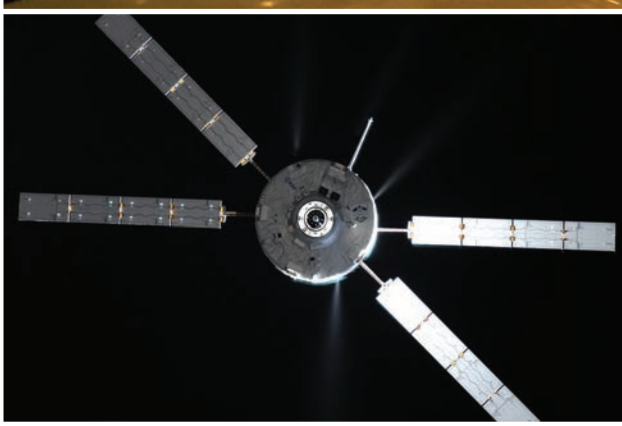


Unmanned ISS Missions

Spacecraft	Launch date	ISS Flight Number	Deorbit
Progress M1-3	6 August 2000	ISS-1P	1 November 2000
Progress M1-4	16 November 2000	ISS-2P	8 February 2000
Progress M-44	26 February 2001	ISS-3P	16 April 2001
Progress M1-6	20 May 2001	ISS-4P	22 August 2001
Progress M-45	21 August 2001	ISS-5P	22 November 2001
Progress M-S01	14 September 2001	ISS-4R	26 September 2001
Progress M1-7	26 November 2001	ISS-6P	20 March 2001
Progress M1-8	21 March 2002	ISS-7P	25 June 2002
Progress M-46	26 June 2002	ISS-8P	14 October 2002
Progress M1-9	25 September 2002	ISS-9P	1 February 2002
Progress M-47	2 February 2003	ISS-10P	28 August 2003
Progress M1-10	8 June 2003	ISS-11P	3 October 2003
Progress M-48	29 August 2003	ISS-12P	28 January 2004
Progress M1-11	29 January 2004	ISS-13P	3 June 2004
Progress M-49	25 May 2004	ISS-14P	30 July 2004
Progress M-50	11 August 2004	ISS_15P	22 December 2004
Progress M-51	23 December 2004	ISS-16P	9 March 2005
Progress M-52	28 February 2005	ISS-17P	16 June 2005
Progress M-53	16 June 2005	ISS-18P	7 September 2005
Progress M-54	8 September 2005	ISS-19P	3 March 2006
Progress M-55	21 December 2005	ISS-20P	19 June 2006
Progress M-56	24 April 2006	ISS-21P	19 September 2006
Progress M-57	24 June 2006	ISS-22P	17 January 2007
Progress M-58	23 October 2006	ISS-23P	27 March 2007
Progress M-59	18 January 2007	ISS-24P	1 August 2007
Progress M-60	12 May 2007	ISS-25P	25 September 2007
Progress M-61	2 August 2007	ISS-26P	22 January 2008
Progress M-62	23 December 2007	ISS-27P	15 February 2008
Progress M-63	5 February 2008	ISS-28P	7 April 2008
ATV	9 March 2008	ISS-ATV1	5 September 2008
Progress M-64	14 May 2008	ISS-29P	8 September 2008
Progress M-65	10 September 2008	ISS-30P	8 December 2008
Progress M-01M	26 November 2008	ISS-31P	8 February 2009
Progress M-66	10 February 2009	ISS-32P	18 May 2009
Progress M-02M	7 May 2009	ISS-33P	13 July 2009
Progress M-67	24 July 2009	ISS-34P	27 September 2009
HTV	10 September 2009	ISS-HTV1	30 October 2009
Progress M-03M	15 October 2009	ISS-35P	27 April 2010
Progress M-MIM2	10 November 2009	ISS-5R	8 December 2009

Spacecraft	Launch date	ISS Flight Number	Deorbit
Progress M-04M	3 February 2010	ISS-36P	1 July 2010
Progress M-05M	28 April 2010	ISS-37P	15 November 2010
Progress M-06M	30 June 2010	ISS-38P	6 September 2010
Progress M-07M	10 September 2010	ISS-39P	20 February 2011
Progress M-08M	27 October 2010	ISS-40P	24 January 2011
HTV	22 January 2011	ISS-HTV2	28 March 2011
Progress M-09M	28 January 2011	ISS-41P	26 April 2011
ATV	16 February 2011	ISS-ATV2	20 June 2011
Progress M-10M	27 April 2011	ISS-42P	29 October 2011
Progress M-11M	21 June 2011	ISS-43P	1 September 2011
Progress M-12M	24 August 2011	ISS-44P	ISS-44P. Failed to orbit; premature third stage cutoff, impacted in the Choisk Region of Russia's Altai Republic.
Progress M-13M	30 October 2011	ISS-45P	25 January 2012
Progress M-14M	25 January 2012	ISS-46P	28 April 2012
ATV	23 march 2012	ISS-ATV3	28 September 2012
Progress M-15M	20 April 2012	ISS-47P	20 August 2012
SpaceX	22 May 2012	ISS-SpX-D	31 may 2012
HTV	21 July 2012	ISS-HTV3	12 September 2012
Progress M-16M	1 August 2012	ISS-48P	9 February 2013
SpaceX	8 October 2012	ISS-SpX-1	28 October 2012
Progress M-17M	31 October 2012	ISS-49P	21 April 2013
Progress M-18M	11 February 2013	ISS-50P	26 July 2013
SpaceX	1 March 2012	ISS-SpX-2	26 March 2013
Progress M-19M	24 April 2013	ISS-51P	19 June 2013
ATV	5 June 2013	ISS-ATV4	28 October 2012
Progress M-20M	27 July 2013	ISS-52P	11 February 2014
HTV	3 August 2013	ISS-HTV4	4 September 2013
Orbital	18 September 2013	ISS-Orb-D1	22 October 2013
Progress M-21M	25 November 2013	ISS-53P	9 June 2014
Orbital	9 January 2014	ISS-Orb-1	18 February 2014
Progress M-22M	5 February 2014	ISS-54P	18 April 2014
Progress M-23M	9 April 2014	ISS-55P	31 July 2014
SpaceX	18 April 2014	ISS-SpX-3	15 May 2014
Orbital	13 July 2014	ISS-Orb-2	15 August 2014
Progress M-24M	23 July 2014	ISS-56P	19 November 2014
ATV	29 July 2014	ISS-SpX-4	25 October 2014
Orbital	28 October 2014	ISS-Orb-3	Lost on Ascent
Progress M-25M	29 October 2014	ISS-57P	25 April 2015

Spacecraft	Launch date	ISS Flight Number	Deorbit
SpaceX	10 January 2015	ISS-SpX-5	10 February 2015
Progress M-26M	17 February 2015	ISS-58P	Planned: 26 August 2015
SpaceX	13 April 2015	ISS-SpX-6	21 May 2015
Progress M-27M	28 April 2015	ISS-59P	Failed to Orbit



Reference

To Learn More

ONLINE:

International Space Station
www.nasa.gov/station

Station Science
www.nasa.gov/iss-science

Canadian Space Agency (CSA)
http://www.asc-csa.gc.ca/eng/iss/

European Space Agency (ESA)
http://www.esa.int/esaHS/iss.html

Japan Aerospace Exploration Agency (JAXA)
http://iss.jaxa.jp/en/

Russian Federal Space Agency (Roscosmos)
http://knts.rsa.ru/
http://www.energia.ru/english/index.html

SOCIAL MEDIA:

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International Space Station

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Acronym List

A

ACU	Arm Control Unit
AED	Automated External defibrillator
A/L	Airlock
AMS	Alpha Magnetic Spectrometer
APFR	Articulating Portable Foot Restraint
ARC	Ames Research Center
ARED	Advanced Resistive Exercise Device
ARIS	Active Rack Isolation System
ASI	Italian Space Agency
ATM	Atmosphere
ATV	Automated Transfer Vehicle

B

BASS-II	Burning and Suppression of Solids - II
BCA	Battery Charging Assembly
BCDU	Battery Charge Discharge Unit
BIOLAB	Biological Laboratory
BRIC	Biological Research in Canisters
BSA	Battery Stowage Assembly

C

C&T	Communications & Tracking
C2V2	Common Communications for Visiting Vehicles
C	Celsius
CATS	Cloud-Aerosol Transport System
CBM	Common Berthing Mechanism
CDRA	Carbon Dioxide Removal Assembly
CEPF	Columbus External Payload Facility
CEVIS	Cycle Ergometer with Vibration Isolation System
CFE	Capillary Flow Experiment
CHECS	Crew Health Care System
CIR	Combustion Integrated Rack
CM	centimeter
CMG	Control Moment Gyroscope
CMO	Crew Medical Officer
CMTF	Canadian MSS Training Facility
CO_2	carbon dioxide
COLBERT	Combined Operational Load Bearing External Resistive Exercise Treadmill
COL-CC	Columbus Control Center
CRPCM	Canadian Remote Power Controller Module
CRS	Commercial Resupply System
CSA	Canadian Space Agency
CWC	Contingency Water Container
CWQMK	Colorimetric Water Quality Monitoring Kit

D

DC	Docking Compartment
DC	Direct Current
DCSU	Direct Current Switching Unit
DDCU	DC-to-DC Converter Unit
DECLIC	Device for the study of Critical Liquids and Crystallization
DRTS	Data Relay Test Satellite

E

EAC	European Astronaut Centre
EADS	European Aeronautic Defence and Space Company
EarthKAM	Earth Knowledge-based Acquired by Middle Schools
ECLSS	Environmental Control and Life Support System
ECU	Electronics Control Unit
EDR	European Drawer Rack
EF	Exposed Facility
EHS	Environmental Health System
ELC	EXPRESS Logistics Carriers
ELITE-S2	ELaboratore Immagini Televisive-Space 2
ELM-ES	Experiment Logistics Module Exposed Section
ELM-PS	Experiment Logistics Module-Pressurized Section
EML	Electromagnetic Levitator
EMU	Extravehicular Mobility Unit
EPM	European Physiology Module
EPS	Electrical Power System
ERA	European Robotic Arm
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
EVA	Extravehicular Activity
EXPRESS	Expedite the Processing of Experiments to the Space Station

F

F	Farenheit
FGB	Functional Cargo Block
FIR	Fluids Integrated Rack
FSL	Fluid Science Laboratory
FT	foot
FT^3	Cubic feet

G

GATOR	Grappling Adaptor to On-Orbit Railing
GCTC	Gagarin Cosmonaut Training Center
GN&C	Guidance, Navigation, and Control
GPS	Global Positioning System
GRC	Glenn Research Center
GSC	Guiana Space Centre

H

H_2	hydrogen
H_2O	water
HDPCG	Hand-Held High Density Protein Crystal Growth
HICO	Hyperspectral Imager for the Coastal Ocean

HMS	Health Maintenance System
HMS CMRS	Health Maintenance System/Crew Medical Restraint System
HQ	Headquarters
HR	hour
HRF	Human Research Facility
HRS	Heat Rejection Subsystem
HTV	H-II Transfer Vehicle

I

ICWS	Iodine Compatible Water Containers
IEA	Integrated Equipment Assembly
IN	inch
IPS	International Partners
IRU	In-Flight Refill Unit
ISPR	International Standard Payload Rack
ISS	International Space Station
ITS	Integrated Truss Structure
IV-TEPC-IV	Tissue Equivalent Proportional Counter

J

JAXA	Japan Aerospace Exploration Agency
JEF - JEM	Exposed Facility
JEM	Japanese Experiment Module
JEM-RMS	Japanese Experiment Module Remote Manipulator System
JLP	Japanese Experiment Logistics Module-Pressurized Section
JPL	Jet Propulsion Laboratory
JPM	Japanese Pressurized Module
JSC	Johnson Space Center

K

K	Kelvin
KG	kilogram
KM	kilometer
KN	Kilonewton
KSC	Kennedy Space Center
KW	kilowatt

L

L	liters
LB	pound
LBF	pound-force
LED	Light Emitting Diode
LEO	Low-Earth orbit
LIOH	Lithium Hydroxide

M

M	meter
M^3	cubic meter
MARES	Muscle Atrophy Research Exercise System
MAS	Microbial Air Sampler
MBPS	Megabits Per Second
MBS	Mobile Base System
MBSU	Main Bus Switching Unit
MCC	Mission Control Center
MCC-H	Mission Control Center-Houston
MELFI	Minus Eighty-Degree Laboratory Freezer for ISS
MERLIN	Microgravity Experiment Research Locker/Incubator
MIL-STD	Military Standard
MLM	Multi-Purpose Laboratory Module
MMOD	Micrometeoroid and Orbital Debris
MN	Meganewton
MOC	MSS Operations Complex
MOTS	MSS Operations and Training System
MPLM	Multi-Purpose Logistics Module
MRM	Mini-Research Module
MSFC	Marshall Space Flight Center
MSG	Microgravity Sciences Glovebox
MSPR	Multipurpose Small Payload Rack
MSRR	Materials Science Research Rack
MSS	Mobile Servicing System

N

N_2	nitrogen
N_2O_4	nitrogen tetroxide
NASA	National Aeronautics and Space Administration
NORS	Nitrogen/Oxygen Resupply System

O

O_2	oxygen
OBSS	Orbiter Boom Sensor System
OEC	Operations Engineering Centre
OGS	Oxygen Generation System
ORU	Orbital Replacement Unit

P

PASSAGES	Scaling Body-Related Actions in the Absence of Gravity
PCM	Pressurized Cargo Module
PDGF	Power Data Grapple Fixture
PLSS	Primary Life Support Subsystem
PMA	Pressurized Mating Adaptor
PMM	Permanent Multipurpose Module
POCS	Payload Operations Centers
POIC	Payload Operations and Integration Center
PS	Pressurized Section
PSA	Power Supply Assembly
PSI	pounds per square inch
PTCS	Passive Thermal Control System
PTOC	Payload Telescience Science Operations Center
PVTCS	Photovoltaic Thermal Control System
PWP	Portable Work Post

R

RAM	Radiation Area Monitor
RMPSR	Remote Multipurpose Support Room
RMS	Remote Manipulator System

RPM	revolutions per minute
RS	Russian Segment
RSC ENERGIA	S.P. Korolev Rocket and Space Corporation Energia
RTS	Remote Terminals

S

SAFER	Simplified Aid For EVA Rescue
SARJ	Solar (Array) Alpha Rotation Joint
SAW	Solar Array Wing
SFOG	Solid Fuel Oxygen Generator
SFP	Space Flight Participant
SLM	Sound Level Meter
SM	Service Module
SPDM	Special Purpose Dexterous Manipulator
SPHERES	Synchronized Position Hold, Engage, Reorient, Experimental Satellites
SPP	Science Power Platform
SS	Service Section
SSA	Space Suit Assembly
SSK	Service Sample Kit
SSP	Space Shuttle Program
SSRMS	Space Station Remote Manipulator System
SSU	Sequential Shunt Unit
STEM	Sciences, Technology, Engineering and Mathematics
STS	Shuttle Transport System

T

TAS-I	Thales Alenia Space Italy
TCS	Thermal Control System
TDRS	Tracking and Data Relay Satellites
TKSC	Tsukuba Space Center
TNSC	Tanegashima Space Center
TOCA	Total organic carbon analyzer
TSCS	Telescience Support Centers
TSUP	Moscow Mission Control Center
TVIS	Treadmill Vibration Isolation System

U

U.S.	United States
UDMH	unsymmetrical dimethyl hydrazine
UHF	Ultra High Frequency
USOC	User Support and Operation Centers
USOS	U.S. On-orbit Segment

V

VDC	voltage, direct current
VDU	Video Distribution Unit
VHF	very high frequency

W

WHC	Waste Hygiene Compartment
WORF	Window Observational Research Facility
WPA	Water Processing Assembly
WRS	Water Recovery System

Definitions

berthing
: Mating or linking operations of two spacecraft, modules, or elements where an inactive module/vehicle is placed into the mating interface using a Remote Manipulator System

common berthing mechanism (cbm)
: The mechanical attachment system used to mate and demate International Space Station (ISS) pressurized elements providing the structural load carrying capability and sealing interface that allows the shirtsleeve transfer of people and supplies between the habitable modules

docking
: Mating or linking operations of two spacecraft, modules, or elements where an active vehicle flies into the mating interface under its own power

element
: A structural component such as a module or truss segment

expedition
: A long-duration crew during a stay on the space station

increment
: Period of time from launch of a vehicle rotating International Space Station crewmembers to the undocking of the return vehicle for that crew

mission
: Flight of a "visiting" Soyuz, or other vehicle not permanently attached to the International Space Station

module
: An internally pressurized element intended for habitation

nadir
: Direction directly below (opposite zenith)

port
: Direction to the left side (opposite starboard)

rendezvous
: Movement of two spacecraft toward one another

space flight participant
: Nonprofessional astronaut

starboard
: Direction to the right side (opposite port)

zenith
: Directly above, opposite nadir

ISS Partners:

United States of America
www.nasa.gov

Canada
www.space.gc.ca/asc/eng/default.asp

Japan
www.jaxa.jp/index_e.html

Russian Federation
www.roscosmos.ru

European Space Agency
www.esa.int

National Aeronautics and Space Administration

Johnson Space Center
2101 Nasa Pkwy
Houston, TX 77058

www.nasa.gov

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