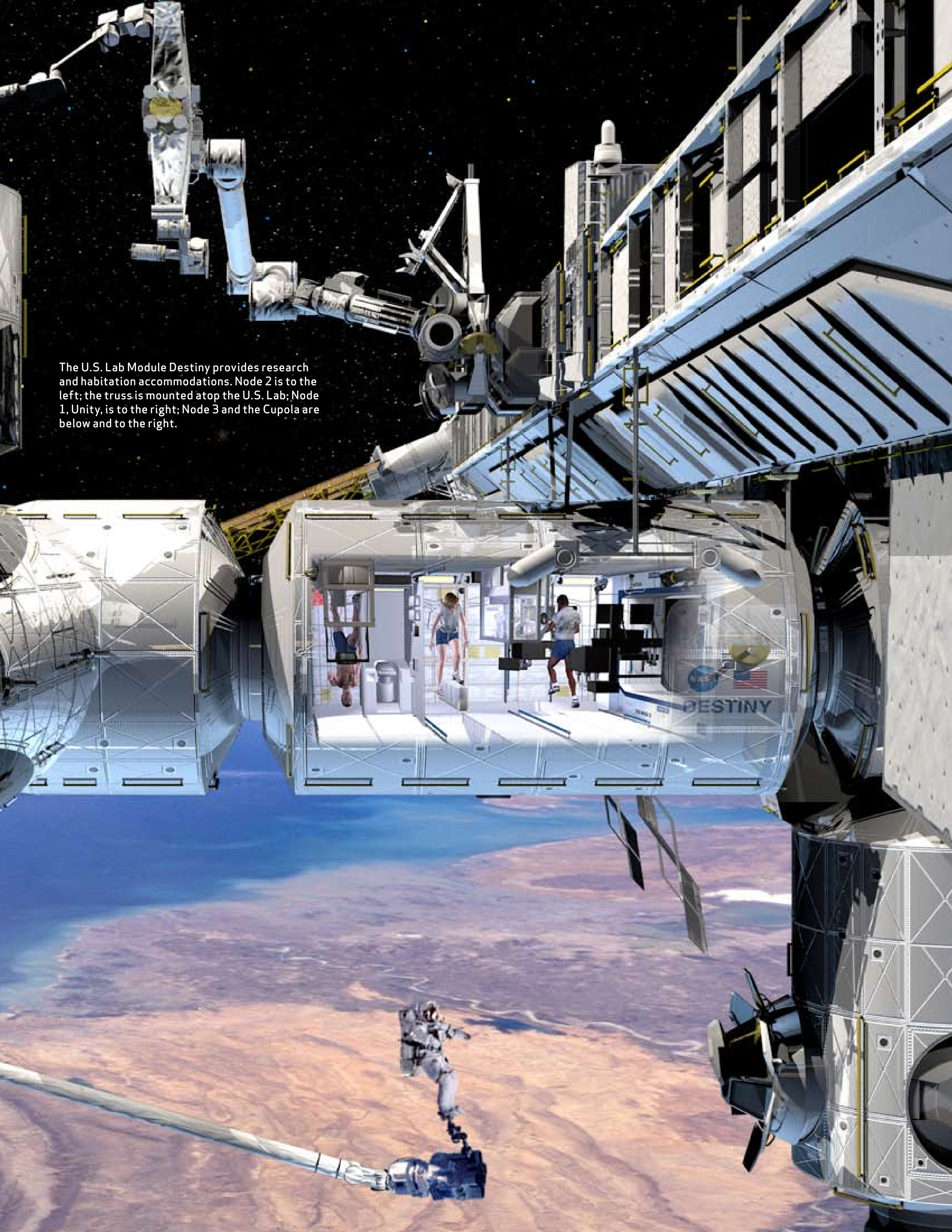
elements

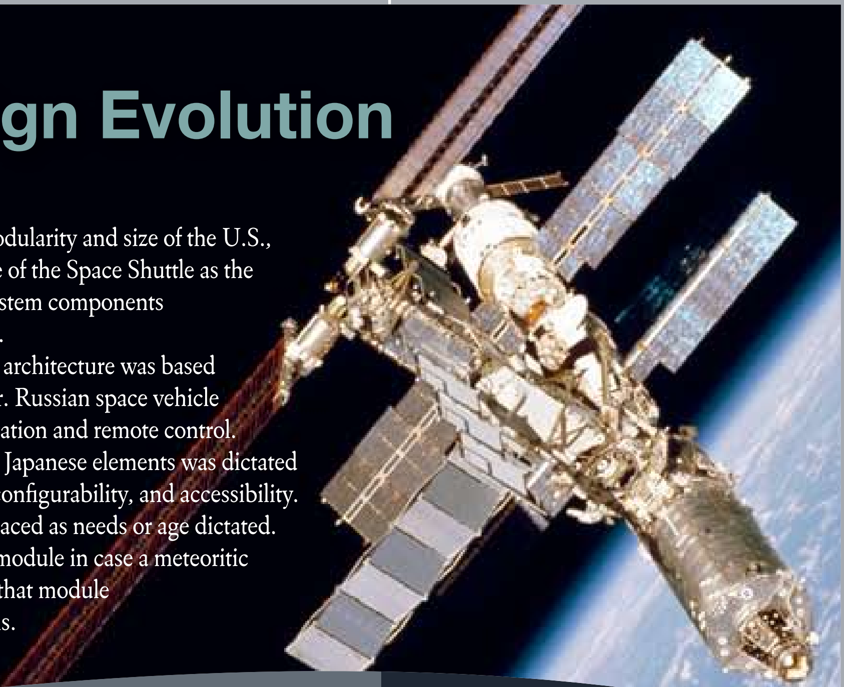
The International Space Station (ISS) is an experiment in the design, development, and assembly of an orbital space facility. It serves as a habitat for its crew, a command post for orbital operations, and a port for the rendezvous and berthing of smaller orbiting vehicles. It functions as an orbital microgravity and life sciences laboratory, a test bed for new technologies in areas like life support and robotics, and a platform for astronomical and Earth observations.

PMA 2 berthed on Node 1 serves as a primary docking port for the Space Shuttle.



The U.S. Lab Module Destiny provides research and habitation accommodations. Node 2 is to the left; the truss is mounted atop the U.S. Lab; Node 1, Unity, is to the right; Node 3 and the Cupola are below and to the right.

Architecture Design Evolution



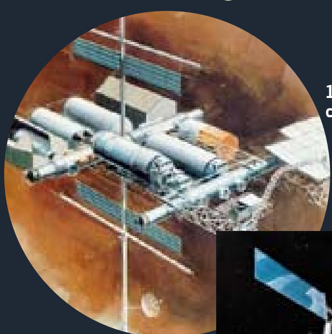
Why does the ISS look the way it does?

The design evolved over more than a decade. The modularity and size of the U.S., Japanese, and European elements were dictated by the use of the Space Shuttle as the primary launch vehicle and by the requirement to make system components maintainable and replaceable over a lifetime of many years.

When the Russians joined the program in 1993, their architecture was based largely on the Mir and Salyut stations they had built earlier. Russian space vehicle design philosophy has always emphasized automated operation and remote control.

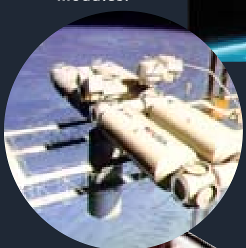
The design of the interior of the U.S., European, and Japanese elements was dictated by four specific principles: modularity, maintainability, reconfigurability, and accessibility. Interior modular hardware racks and utilities could be replaced as needs or age dictated. Racks could be swung away from the pressure hull of the module in case a meteoritic puncture necessitated a repair. Crew preferences dictated that module interiors be arranged with distinct floors, ceilings, and walls.

Module Design and Layout

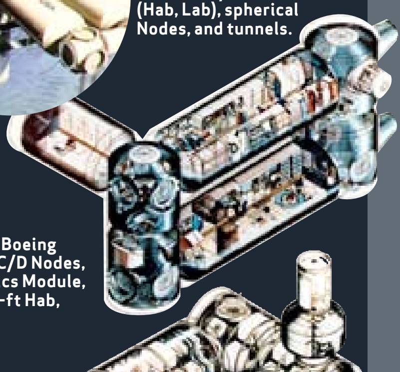


1979—Modules with connecting tunnels.

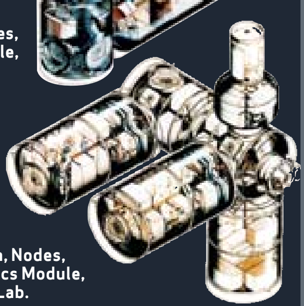
1982—Common modules.



1986—Habitation Module, Laboratory Module (Hab, Lab), spherical Nodes, and tunnels.

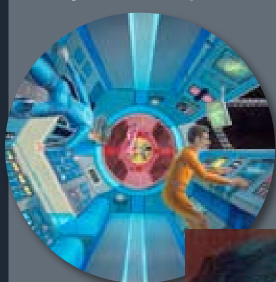


1988—Boeing Phase C/D Nodes, Logistics Module, and 45-ft Hab, Lab.

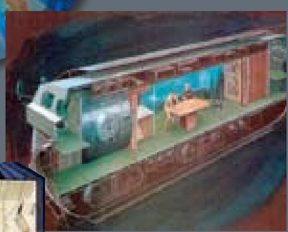


1992—Freedom, Nodes, Airlock, Logistics Module, and 27-ft Hab, Lab.

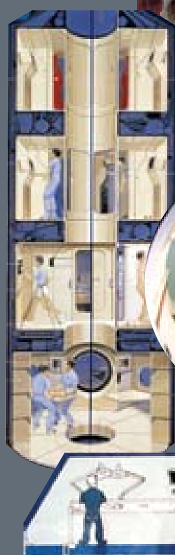
Module Architecture Early Concepts



1980—Horizontal layout.



1980—Horizontal layout.



1980—Vertical layout.

1986—Central core.

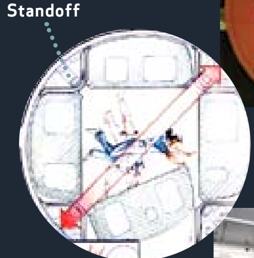
1986—Central beam.

Module Architecture Racks with Four Structural Standoffs

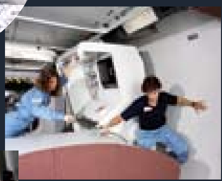
Loft concept.

Modular outfitting.

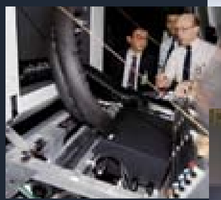
Standard racks (2 sizes).



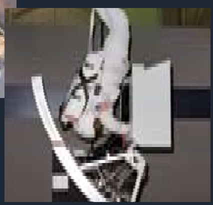
Standard rack (1 size).



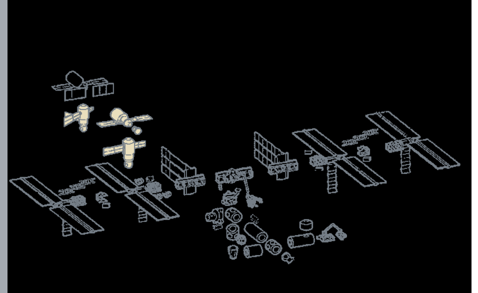
Access to module pressure shell.

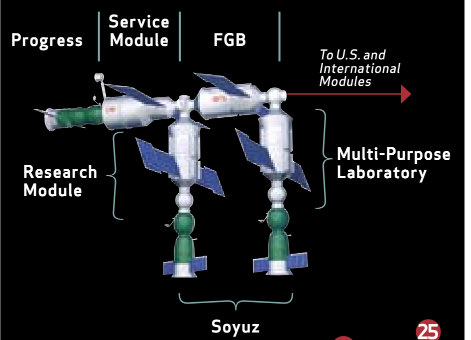


Access to utility runs in standoffs.



Intravehicular EMU access.



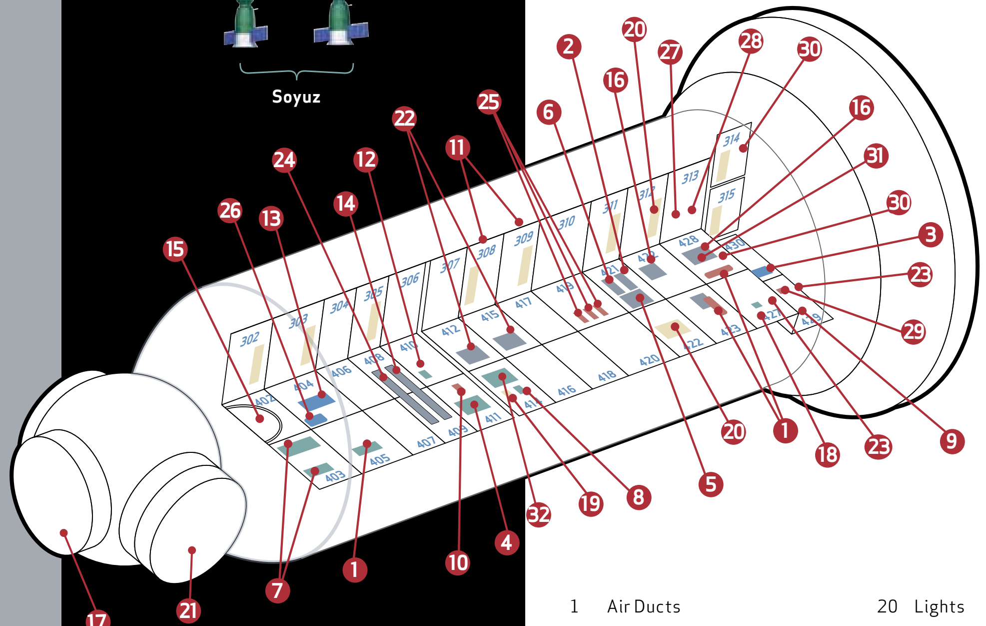


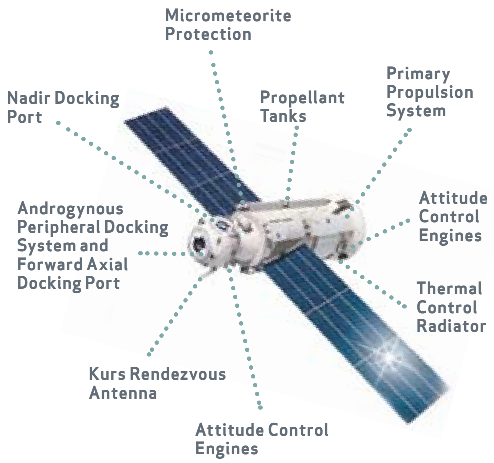
Functional Cargo Block (FGB)

Zarya (Sunrise) and Russian Research Modules

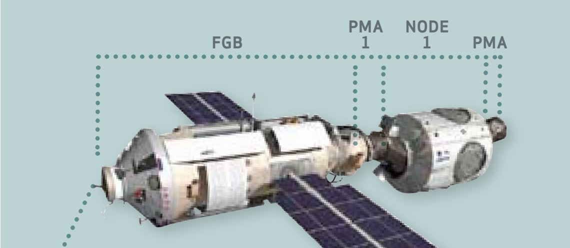
NASA/Khrunichev Production Center

The FGB was the first element of the International Space Station, 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. The FGB module is now used primarily for storage and propulsion. The FGB was based on the modules of Mir. The Russian Multipurpose Modules planned for the ISS will be based on the FGB-2, a spare developed as a backup to the FGB. The Russian Research Module may be based on the FGB design.



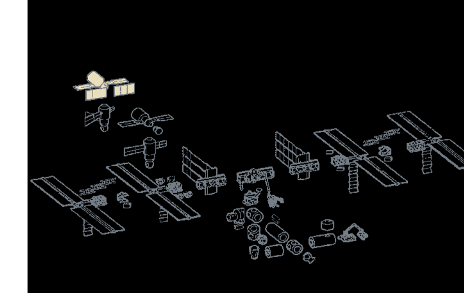


1 Air Ducts
2 Communications Panel
3 Caution and Warning Systems Panel
4 Contaminant Filters
5 Contingency Transfer (Water) Container Bag
6 Contingency Transfer (Water) Container Connections
7 Dust Collectors
8 Electrical Outlet
9 Flex Airduct Container
10 Fuse
11 Fuse Panels (behind close-outs)
12 Gas 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



Probe/Drogue Docking System and Aft (Service Module) Axial Docking Port

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 m^3 (2,525 ft^3)
Solar array span	24.4 m (80 ft)
Array surface area	28 m^2 (301 ft^2)
Power supply (avg.)	3 kW
Propellant mass	3,800 kg (8,377 lb)
Launch date	Nov. 20, 1998, on a Proton rocket

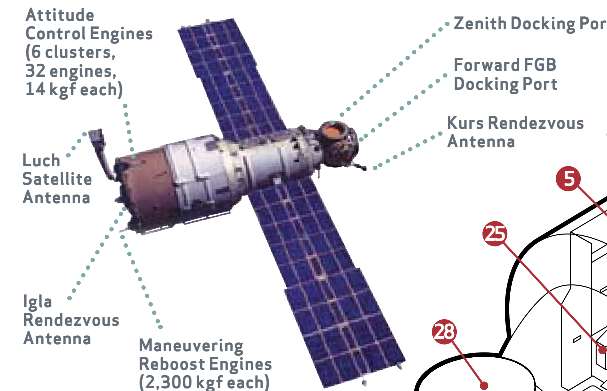


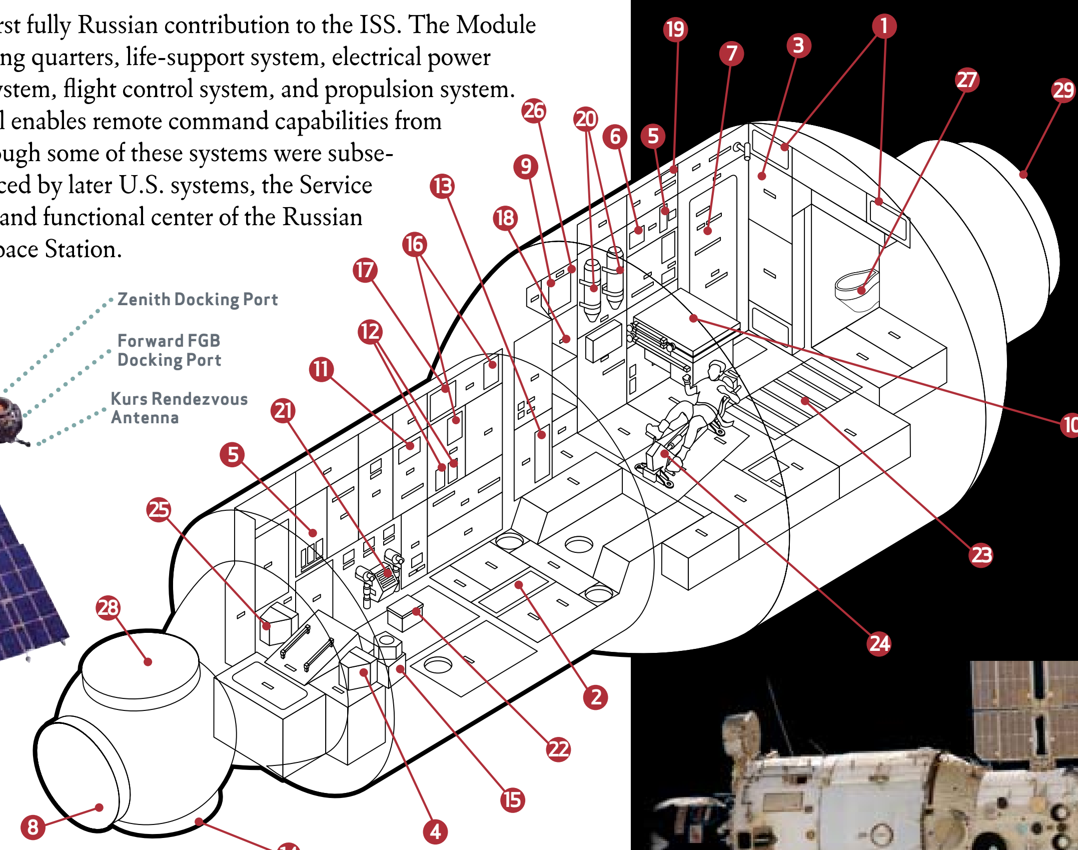
Service Module (SM)

Zvezda (Star)

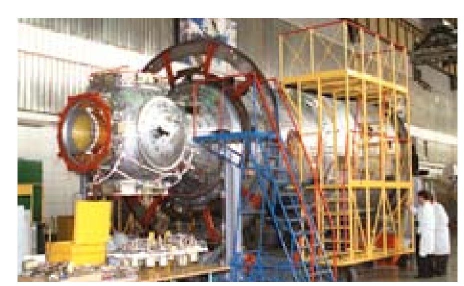
S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

The Service Module was the first fully Russian contribution to the ISS. The Module provided the Station's 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 or replaced by later U.S. systems, the Service Module remains the structural and functional center of the Russian segment of the International Space Station.



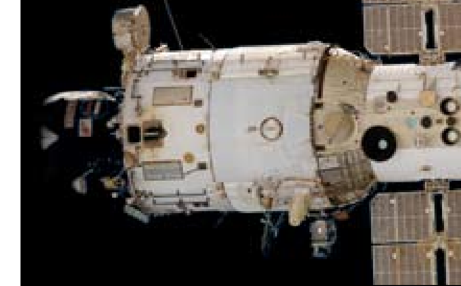


1 Airflow Vent
2 Body Mass Measurement Device
3 Camera
4 Caution and Warning Panel, Clock, and Monitors
5 Communications Panel
6 Condensate Water Processor
7 Crew Sleep Compartment
8 Forward Docking Port (to FGB)
9 Fuses
10 Galley Table
11 Integrated Control Panel
12 Lighting Control Panels
13 Maintenance 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

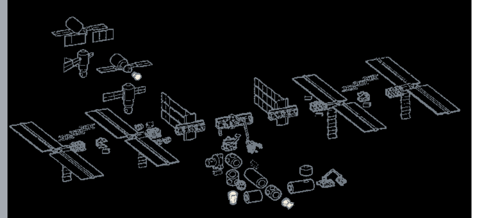


The SM under construction at Khrunichev State Research and Production Space Center in Moscow.

Leroy Chiao exercises in the SM.



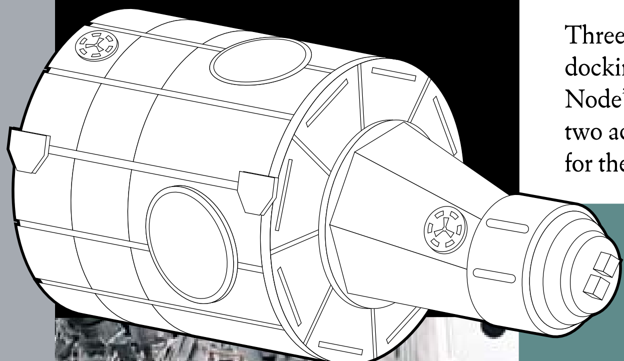
Length	13.1 m (43 ft)
Diameter	4.2 m (13.5 ft)
Wingspan	29.7 m (97.5 ft)
Weight	24,604 kg (54,242 lb)
Launch date	July 11, 2000, on a Proton rocket
Attitude control	32 engines
Orbital maneuvering	2 engines



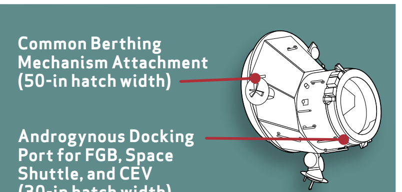
Pressurized Mating Adapters (PMAs)

NASA/Boeing

Three conical docking adapters, called Pressurized Mating Adapters, allow the docking systems used by the Space Shuttle and by Russian modules to attach to the Node's berthing mechanisms. PMA 1 links the U.S. and Russian segments. The other two adapters serve as docking ports for the Space Shuttle and will do the same for the Crew Exploration Vehicle (CEV) and later commercial vehicles.



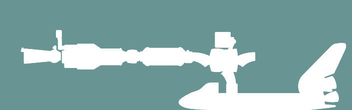
EVA during mission 2A.2a with a view of PMA 1 between the FGB and Node 1.



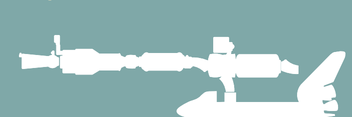
ASSEMBLY PROGRESSES

STAGE 4A/MISSION 2A.2B/STS-101

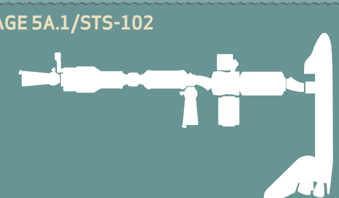
STAGE 4A/STS-97



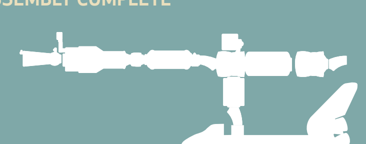
STAGE 5A/STS-98



STAGE 5A.1/STS-102

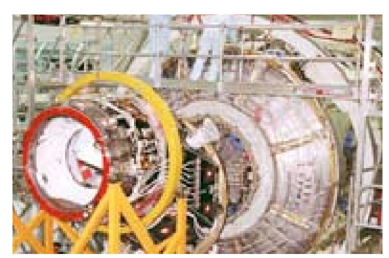


ASSEMBLY COMPLETE



PMA structure shows a series of offset aluminum cylinders.

The PMA 1, 2, and 3 structures are identical and provide a pressurized interface between the U.S. and Russian ISS modules and between the U.S. modules and the Space Shuttle orbiter. The PMA structure is a truncated conical shell with a 28-inch axial offset in the diameters between the end rings.



PMA 1 is being attached to the Common Berthing Mechanism of Node 1.

PMA 2 on the forward berthing ring of Node 1.

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 PMA 2 PMA 3	 1,589 kg (3,504 lb) 1,376 kg (3,033 lb) 1,183 kg (2,607 lb)
Launch Date	
PMAs 1 and 2	Dec. 4, 1998 STS-88/ISS-2A
PMA 3	Oct. 11, 2000 STS-92/ISS-3A

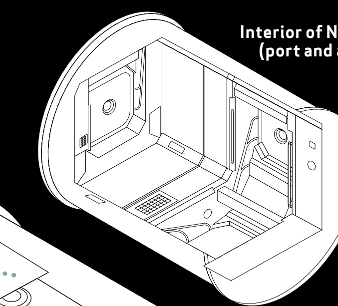
Nodes

Node 1 (Unity), Node 2, Node 3

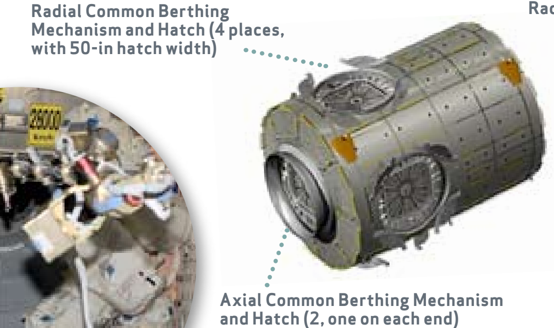
NASA/Boeing, Alcatel Alenia Space

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

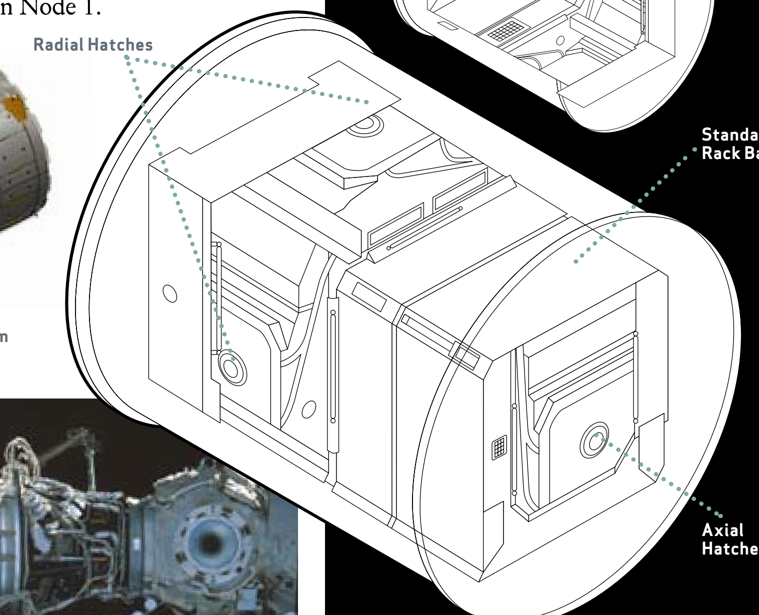
Node 2 will connect the U.S., European, and Japanese laboratories. Node 3, still in development, will provide additional habitation functions, including hygiene and sleeping compartments. Nodes 2 and 3 are slightly longer than Node 1.



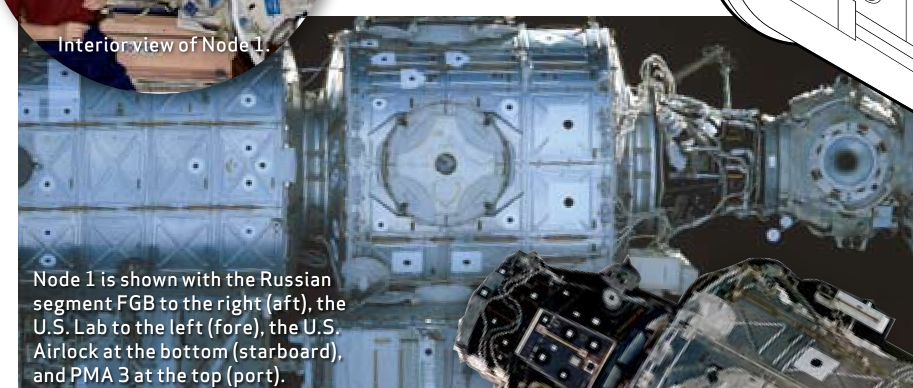
Interior of Node 1 deck (port and aft shown).



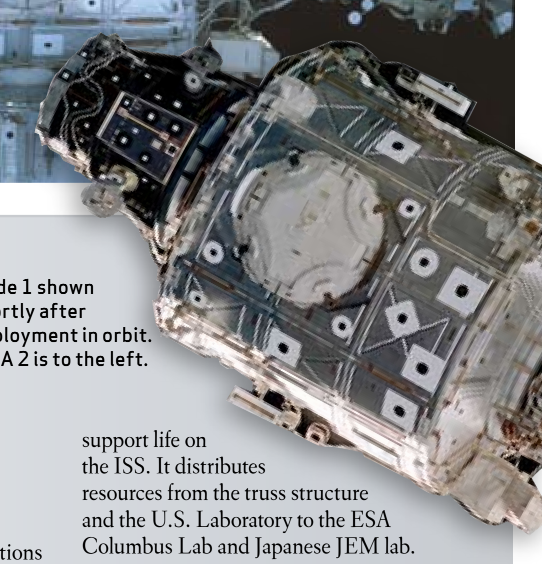
Interior view of Node 1.



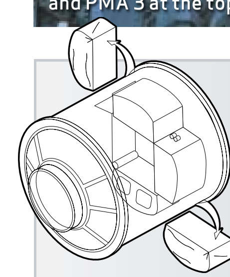
Interior of Node 1 (ceiling, port, and forward endcone shown).



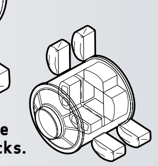
Node 1 is shown with the Russian segment FGB to the right (aft), the U.S. Lab to the left (fore), the U.S. Airlock at the bottom (starboard), and PMA 3 at the top (port).



Node 1 shown shortly after deployment in orbit. PMA 2 is to the left.



Placement of 4 racks in Node 1.



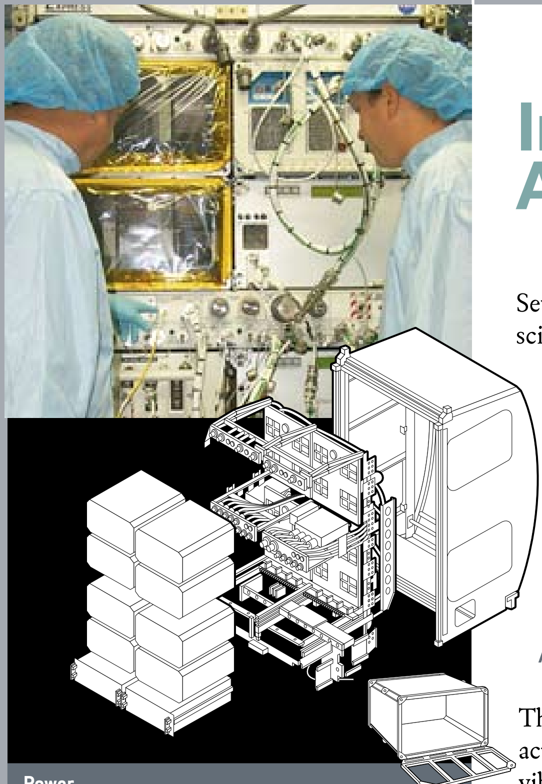
Nodes 2 and 3 have locations for 8 racks.

NODE 1's six ports provide berthing connections to the Z1 Truss, U.S. Lab Module, Airlock, Node 3, and the PMAs. The Multi-Purpose Logistics Module (MPLM) logistics carriers are berthed at Node 1 during some Shuttle visits.

NODE 2 is a "utility hub," providing air, electrical power, water, and other systems essential to support life on the ISS. It distributes resources from the truss structure and the U.S. Laboratory to the ESA Columbus Lab and Japanese JEM lab.

NODE 3 will be attached to the nadir (Earth-facing) radial port of Node 1. Node 3 will provide an attachment point for a PMA, to which the Space Shuttle or CEV can dock. The Cupola will be berthed on Node 3's forward port. Additional ports are available for further ISS additions.

Length of Node 1 Node 2, 3	 5.5 m (18 ft) 6.1 m (21 ft)
Width (diameter)	4.3 m (14 ft)
Mass of Node 1 Node 2 Node 3	 11,895 kg (26,225 lb) 13,508 kg (29,781 lb) TBD
Exterior	Aluminum cylindrical sections, 2 endcones
Number of racks for Node 1 Node 2–3	 4 8
Node 1 launch date	Dec. 1998, ISS-2A, STS-88



Power	
3, 6, or 12 kW, 114.5–126 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 517–827 kPa, nominal 1,379 kPa, maximum
Argon, carbon dioxide, helium	517–768 kPa, nominal 1,379 kPa, maximum
Cooling Loops	
Moderate temperature	16.1 °C–18.3 °C
Flow rate	0–45.36 kg/h
Low temperature	3.3 °C–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

Internal Research Accommodations

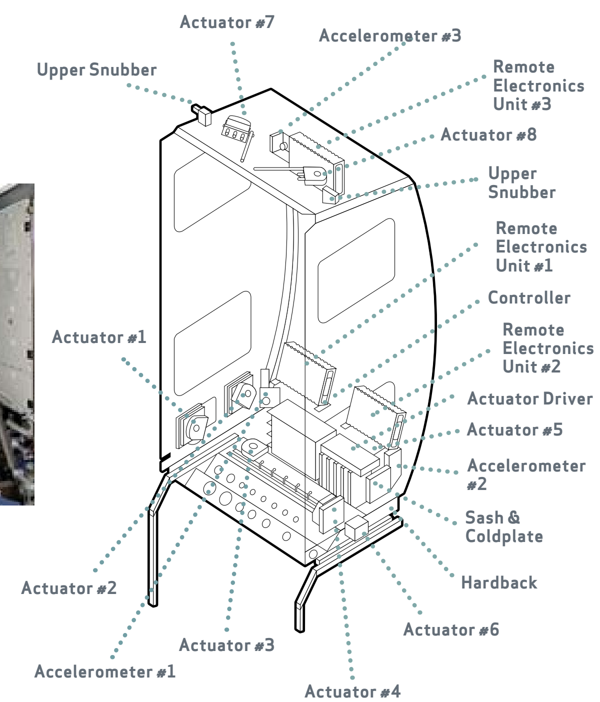
Several research facilities are in place aboard the Station to support science investigations.

Standard Payload Racks

Research payloads 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 a Shuttle middeck locker equivalent and be 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.




Crew installs a rack in the U.S. Lab in orbit.

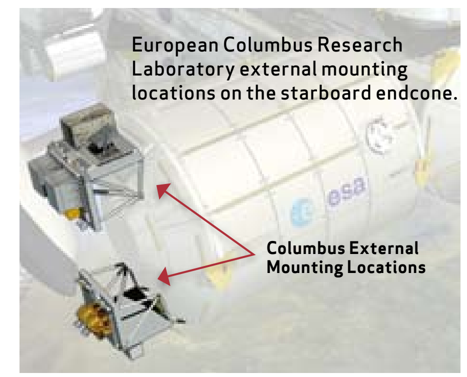
Research Rack Locations

International Pressurized Sites	Station-Wide	U.S. Shared
U.S. Laboratory	13	13
Japanese Experiment Module	11	5
European Columbus Research Laboratory	10	5
Total	34	23


Installation of a rack in the U.S. Lab prior to launch.

External Research Accommodations

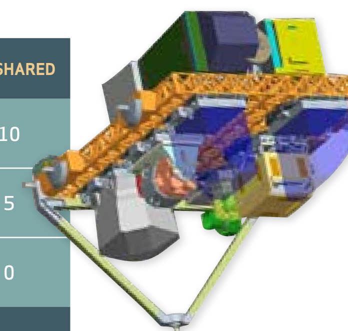
Many locations are available for the mounting of payloads or experiments on the outside of the Station: on the U.S. Truss, on the Russian elements, and additional accommodations will be provided when the Japanese Experiment Module (JEM) Exposed Facility (EF) and Columbus modules are attached.




JEM-EF in preparation for launch.

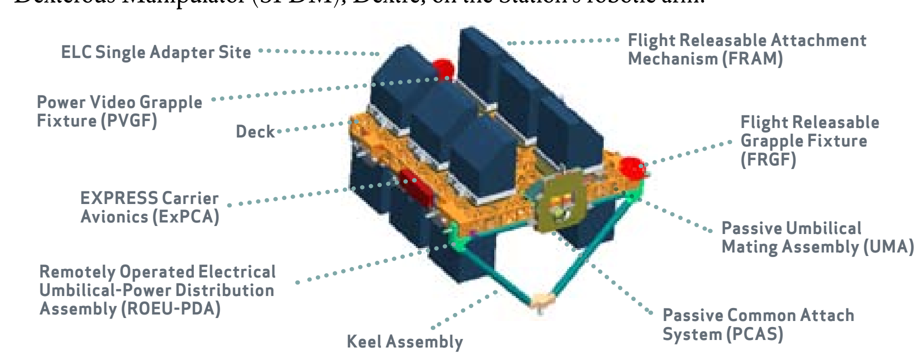
External Research Locations

External Unpressurized Attachment Sites	Station-Wide	U.S. Shared
U.S. Truss	10	10
Japanese Exposed Facility	10	5
European Columbus Research Laboratory	4	0
Total	24	15

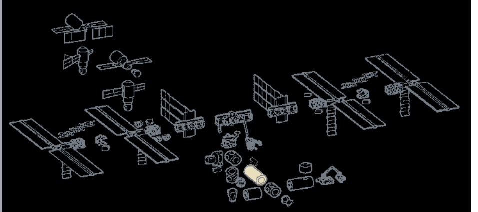


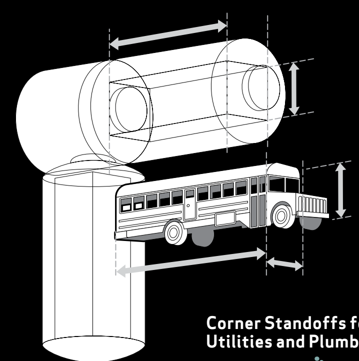
External Payload Accommodations

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 Station's robotic arm.



Express Logistics Carrier (ELC) Resources	
Mass capacity	4,445 kg (9,800 lb)
Volume	30 m^3
Power	3 kW maximum, 113-126 VDC
Low-rate data	1 Mbps (MIL-STD-1553)
High-rate data	95 Mbps (shared)
Local area network	6 Mbps (802.3 Ethernet)
ELC Single Adapter Resources	
Mass capacity	227 kg (500 lb)
Volume	1 m^3
Power	750 W, 113-126 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)
JEM-EF Resources	
Mass capacity	550 kg (1,150 lb) at standard site 2,250 kg (5,550 lb) at large site
Volume	1.5 m^3
Power	3-6 kW, 113-126 VDC
Thermal	3-6 kW cooling
Low-rate data	1 Mbps (MIL-STD-1553)
High-rate data	43 Mbps (shared)
European Columbus Research Laboratory Resources	
Mass capacity	230 kg (500 lb)
Volume	1 m^3
Power	2.5 kW total to carrier (shared)
Thermal	Passive
Low-rate data	1 Mbps (MIL-STD-1553)
Medium-rate data	2 Mbps (shared)



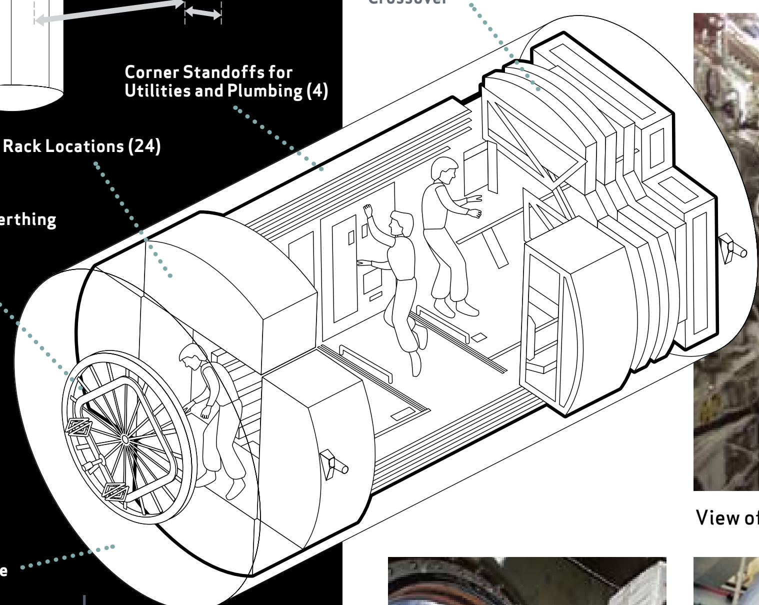


U.S. Laboratory Module (Destiny)

NASA/Boeing

The U.S. Lab provides internal interfaces to accommodate the resource requirements of 24 equipment racks. Approximately half of these are for accommodation and control of ISS systems, and the remainder support scientific research.

Destiny was the first research module installed on the Station. The side of Destiny that usually faces Earth contains a large circular window of very high optical quality.

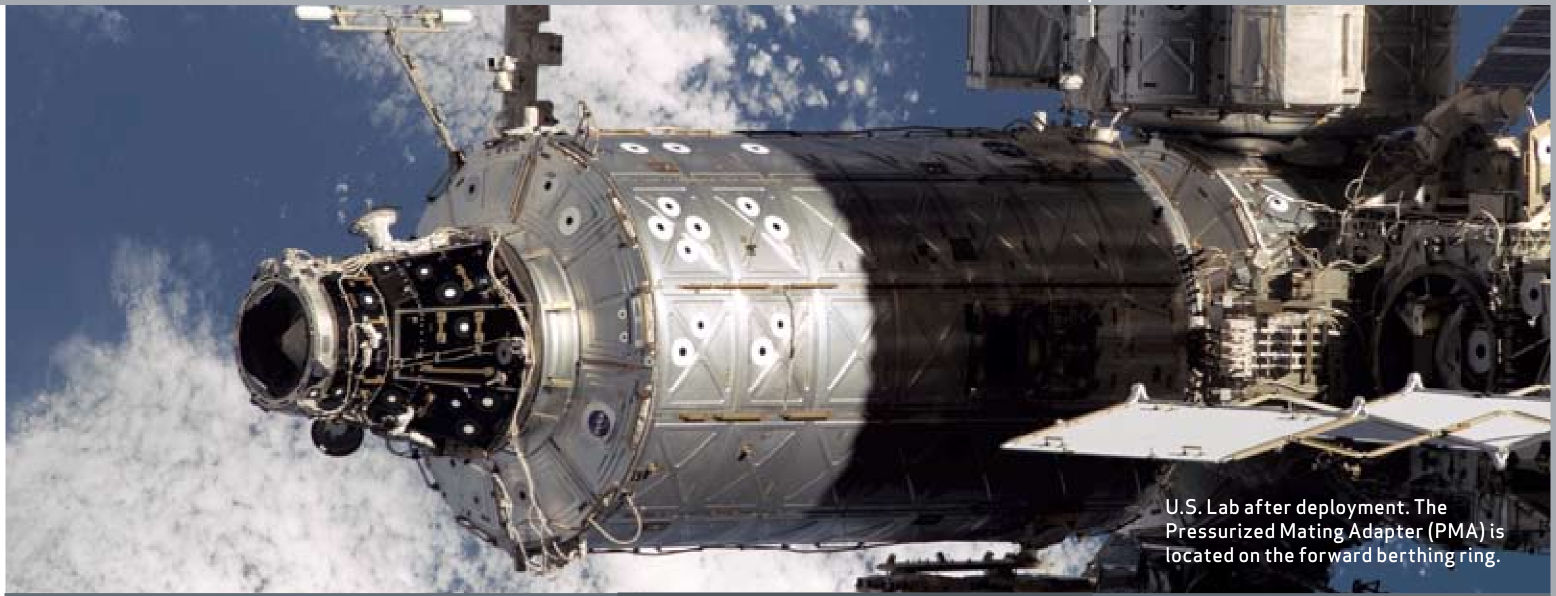


View of astronaut Ed Lu in the U.S. Lab.

Astronaut Susan Helms at the 20-inch-diameter circular window.

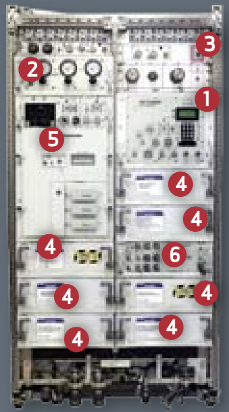
Module in preparation at Kennedy Space Center (KSC).

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)
Mass	14,515 kg (32,000 lb) 24,023 kg (52,962 lb) with all racks and outfitting
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	Feb. 7, 2001, assembly flight 5A, STS-98

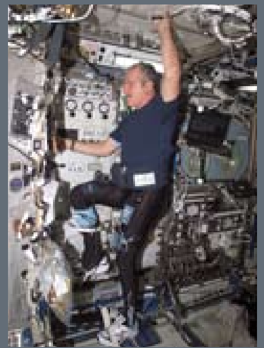


U.S. Lab after deployment. The Pressurized Mating Adapter (PMA) is located on the forward berthing ring.

The **Human Research Facility (HRF)** supports a variety of life sciences experiments. It includes equipment for lung function tests, ultrasound equipment to image the heart, and many other types of computers and medical equipment.

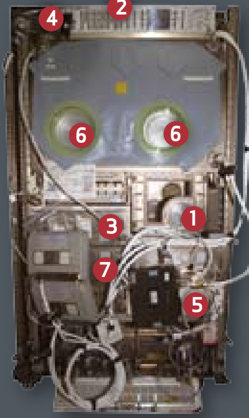


1 Gas Analyzer System for Metabolic Analysis Physiology (GASMAP)
2 GASMAP Gas Calibration Module (GCM)
3 Power Switch and Data Interconnects
4 Stowage Drawers
5 Ultrasound Imaging System
6 Workstation Interface



John Phillips conducts Foot Reaction Forces (FOOT) experiment on HRF rack.

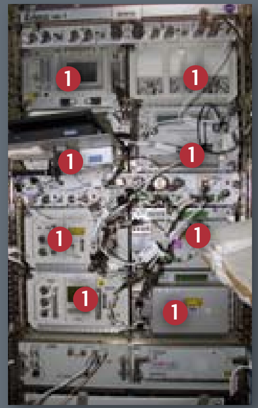
The **Microgravity Science Glovebox** provides a sealed environment for conducting science and technology experiments. It has a large front window and built-in gloves, data storage and recording capabilities, and an independent air circulation and filtration system.



1 Airlock
2 Control and Monitoring Panel
3 Power Distribution Box
4 Power Switches
5 Remote Power Distribution
6 Work Volume Armholes
7 Video

William McArthur uses the Microgravity Science Glovebox.

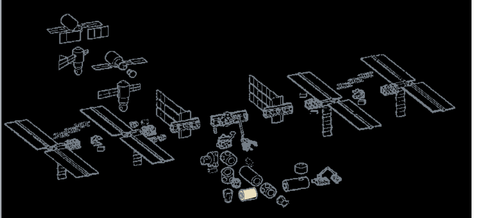
The five **EXPRESS Racks** provide sub-rack-sized experiments with standard utilities such as power, data, cooling, fluids, and gases. The racks stay in orbit, while experiments are changed as needed.



1 Stowage or Payload Locations

The **Minus Eighty-Degree Laboratory Freezer for ISS (MELFI)** provides refrigerated storage and fast-freezing of biological and life science samples. It can hold up to 300 L of samples ranging in temperature from 4 °C to a low of -80 °C.

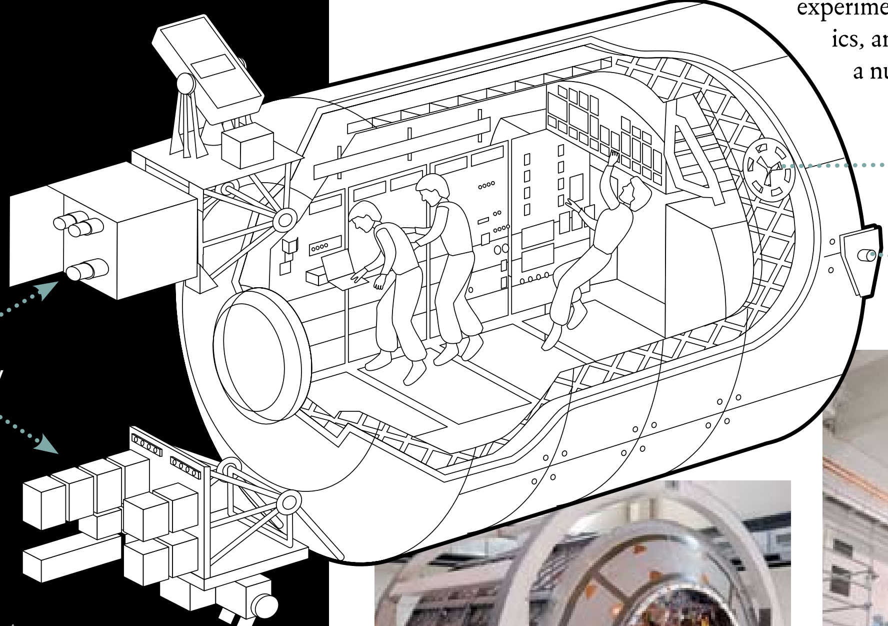
1 Refrigerated/Frozen Storage Dewars



Columbus Research Laboratory

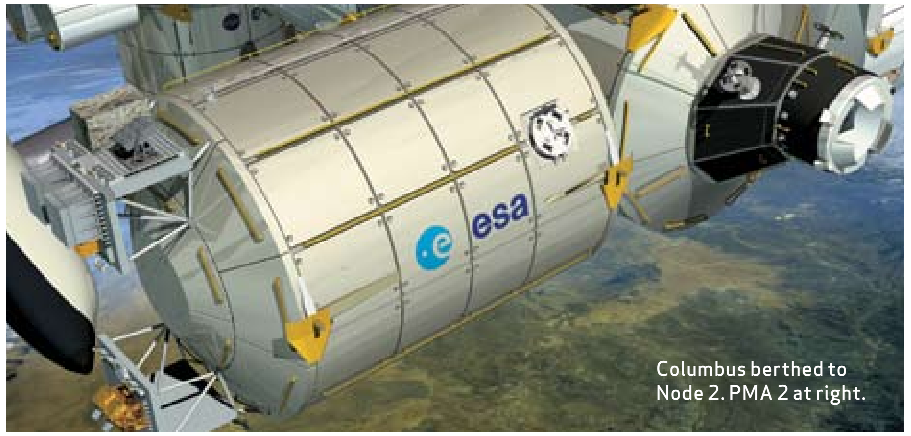
European Space Agency (ESA)/European Aeronautic Defence and Space Co. (EADS) Space Transportation

The Columbus Research Laboratory is Europe's largest contribution to the construction of the International Space Station. It will support scientific and technological research in a microgravity environment. Columbus, a program of ESA, is a multifunctional pressurized laboratory that will be permanently attached to Node 2 of the ISS to carry out experiments in materials science, fluid physics, and biosciences, as well as to perform a number of technological applications.



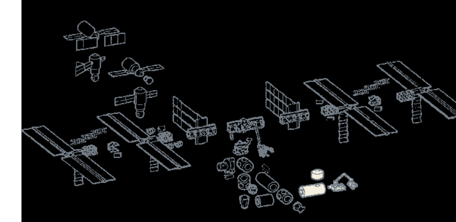
Columbus lab being prepared for shipment to the United States by ESA technicians.

Columbus lab at Kennedy Space Center in preparation for launch.



Columbus berthed to Node 2. PMA 2 at right.

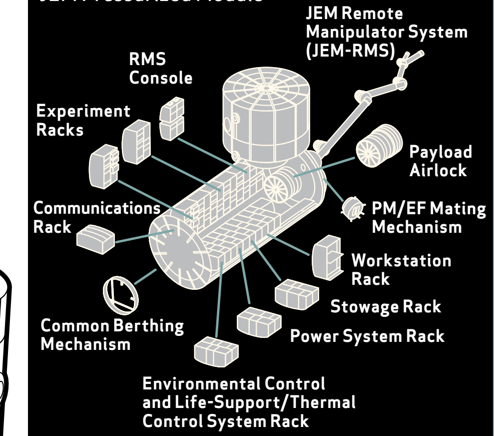
Length	6.9 m (22.6 ft)
Diameter	4.5 m (14.7 ft)
Mass without payload with payload	 10,300 kg (22,700 lb) 19,300 kg (42,550 lb)
Racks	10 International Standard Payload Racks (ISPRs)

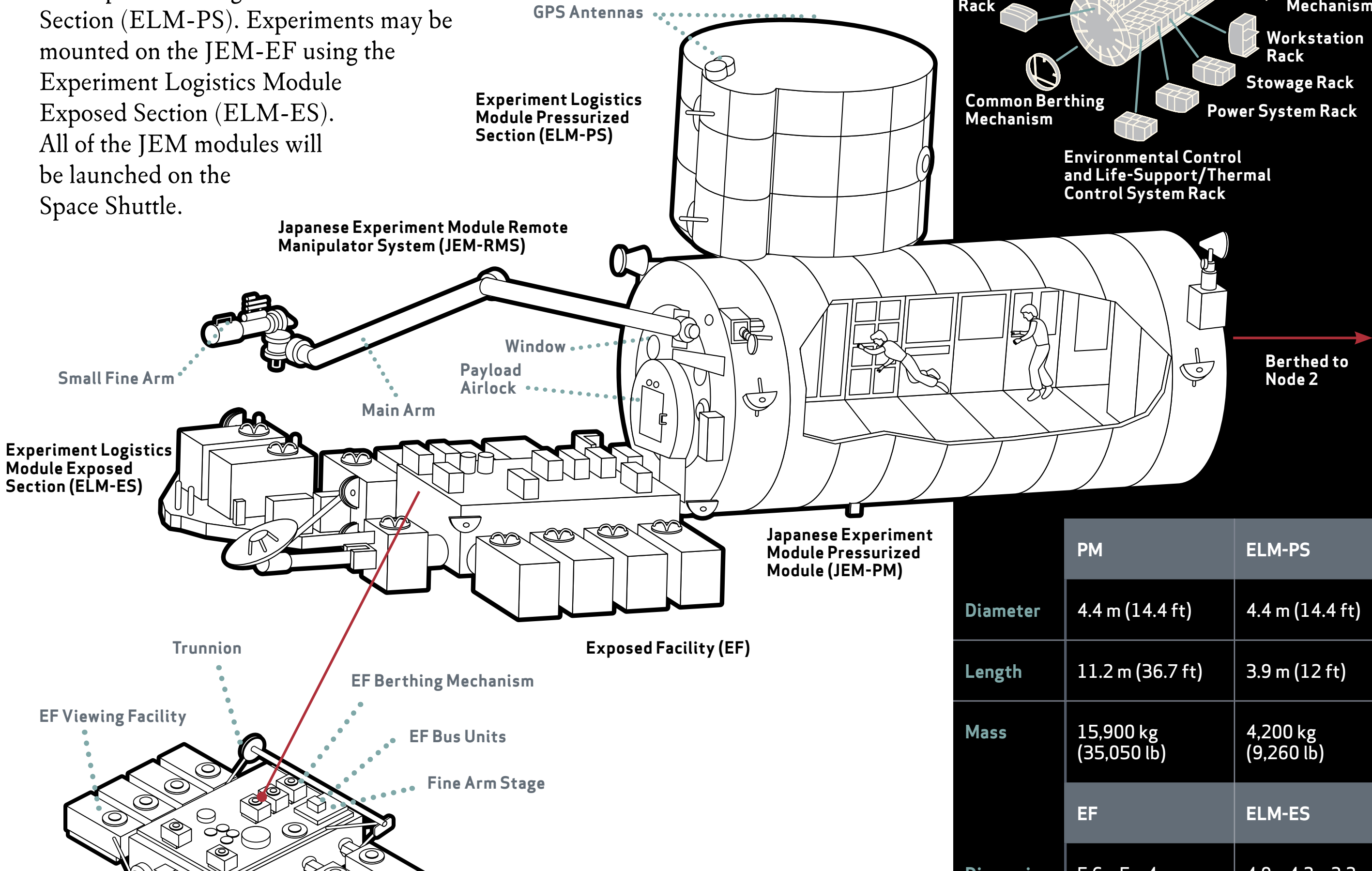


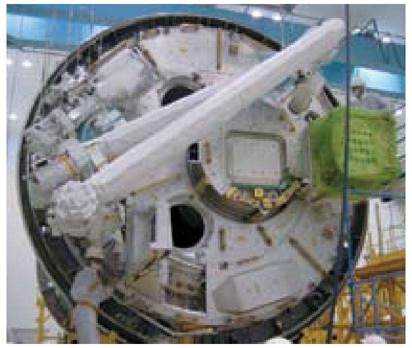
Japanese Experiment Module (JEM)/Kibo (Hope)

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

The Japanese Experiment Module is the first crewed space facility ever developed by Japan. The Pressurized Module (PM) is used mainly for microgravity experiments. The Exposed Facility (EF) is located outside the pressurized environment of the ISS. Numerous experiments that require direct exposure can be mounted with the help of the JEM remote manipulator and airlock. Logistics components will be launched in the Experiment Logistics Module Pressurized Section (ELM-PS). Experiments may be mounted on the JEM-EF using the Experiment Logistics Module Exposed Section (ELM-ES). All of the JEM modules will be launched on the Space Shuttle.

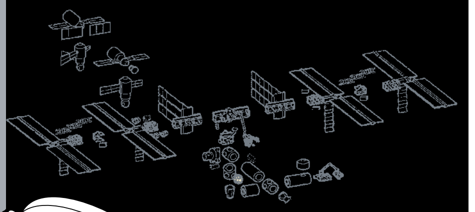






JEM-PM during testing.

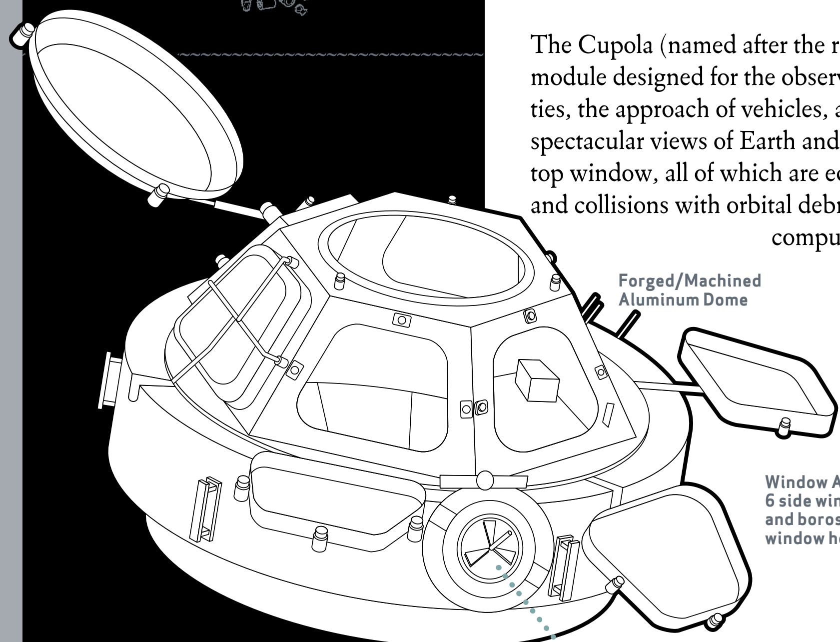
	PM	ELM-PS
Diameter	4.4 m (14.4 ft)	4.4 m (14.4 ft)
Length	11.2 m (36.7 ft)	3.9 m (12 ft)
Mass	15,900 kg (35,050 lb)	4,200 kg (9,260 lb)
	EF	**ELM-ES**
Dimensions	5.6 x 5 x 4 m (18.4 x 16.4 x 13.1 ft)	4.9 x 4.2 x 2.2 m (16.1 x 13.8 x 7.2 ft)
Mass	4,000 kg (8,820 lb)	1,200 kg (2,650 lb)
Racks	10	3
JEM Remote Manipulator System		
Main Arm length		9.9 m (32.5 ft)
Small Fine Arm length		1.9 m (6.2 ft)



Cupola

NASA/Boeing, ESA/Alcatel Alenia Space

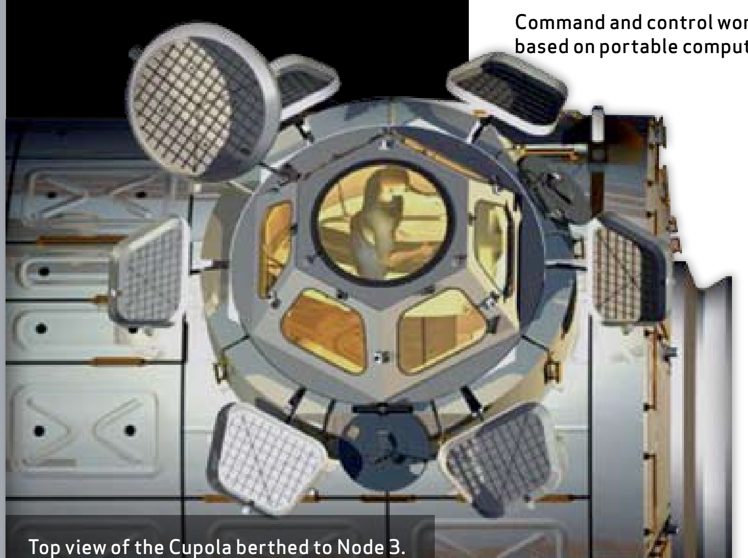
The Cupola (named after the raised observation deck on a railroad caboose) is a small module designed for the observation of operations outside the ISS such as robotic activities, the approach of vehicles, and extravehicular activity (EVA). It will also provide spectacular views of Earth and celestial objects. The Cupola has six side windows and a top 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 computer workstations that control the ISS and the remote manipulators. It can accommodate two crewmembers simultaneously and is berthed to a Node using the Common Berthing Mechanism (CBM).



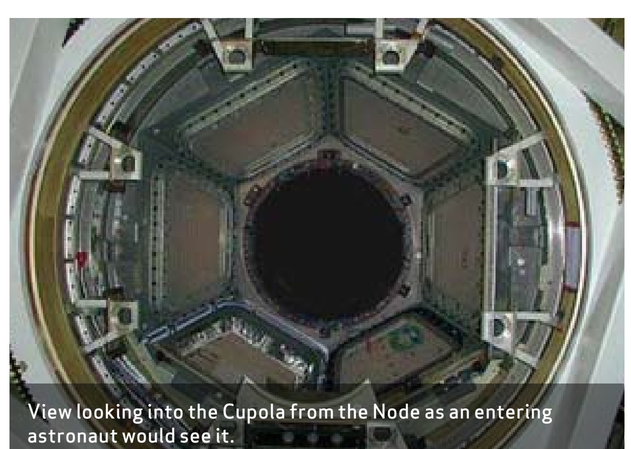
Length	3 m (9.8 ft)
Height	1.5 m (4.7 ft)
Diameter	3 m (9.8 ft)
Mass	1,880 kg (4,136 lb)
Capacity	2 crewmembers with portable workstation

Command and control workstation based on portable computer system.

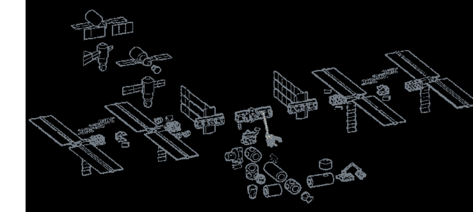
The Cupola in development.



Top view of the Cupola berthed to Node 3.



View looking into the Cupola from the Node as an entering astronaut would see it.

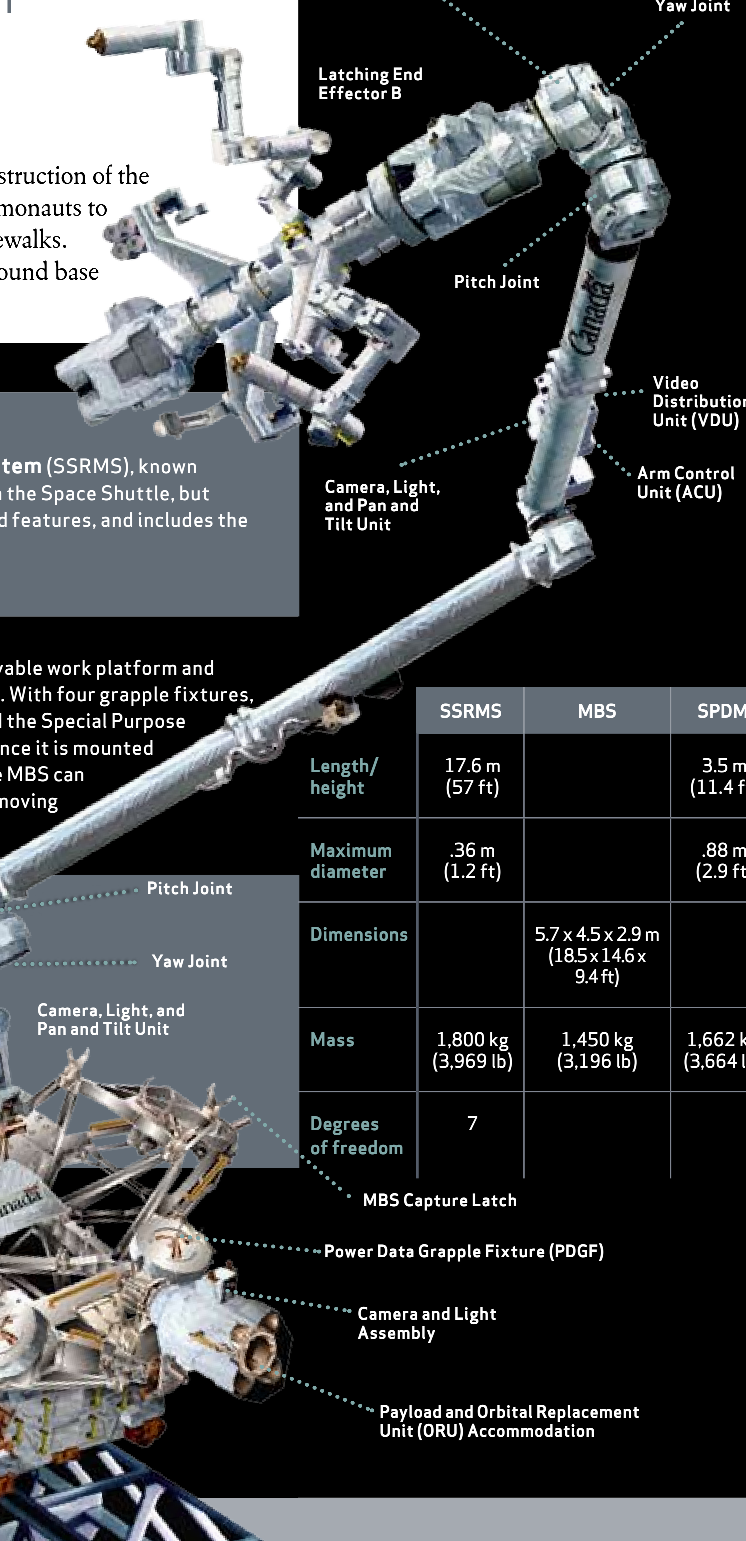


Mobile Servicing System (MSS)

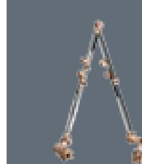
Space Station Remote Manipulator System (SSRMS) and Special Purpose Dexterous Manipulator (SPDM/Dextre)

Mobile Base System (MBS), Canadian Space Agency (CSA)/MacDonald, Dettwiler and Associates, Ltd.

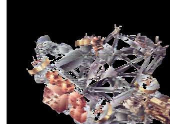
The Mobile Servicing System (MSS) plays a key role in the construction of the ISS and general Station operations. It allows astronauts and cosmonauts to work from inside the Station, thus reducing the number of spacewalks. The MSS Operations Complex in Longueuil, Quebec, is the ground base for the system.



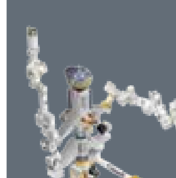
The MSS has three parts:



The Space Station Remote Manipulator System (SSRMS), known as Canadarm 2, is similar to the Canadarm used on the Space Shuttle, but Canadarm 2 is larger, incorporates many advanced features, and includes the ability to self-relocate.



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 Canadarm 2 and the Special Purpose Dexterous Manipulator (SPDM) simultaneously. Since it is mounted on the U.S.-provided Mobile Transporter (MT), the MBS can move key elements to their required worksites by moving along a track system mounted on the ISS truss.



The Special Purpose Dexterous Manipulator (SPDM) has a dual-arm design that can remove and replace smaller components on the Station's exterior, where precise handling is required. It will be equipped with lights, video equipment, and a tool platform, as well as four tool holders.

	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 x 4.5 x 2.9 m (18.5 x 14.6 x 9.4 ft)	
Mass	1,800 kg (3,969 lb)	1,450 kg (3,196 lb)	1,662 kg (3,664 lb)
Degrees of freedom	7		

SSRMS during testing.

Scott Parazynski removes orbital debris shield to connect SSRMS wiring.