systems

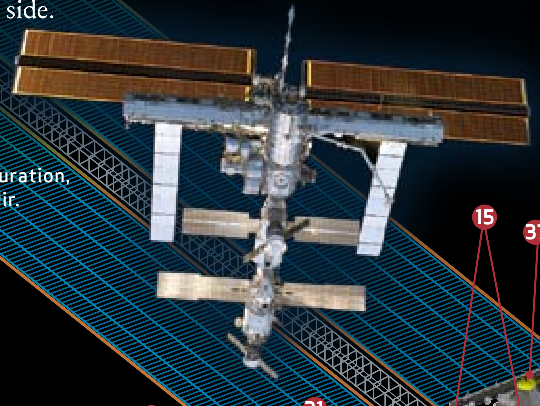
The International Space Station (ISS) flight systems make up the core functional infrastructure of the on-orbit ISS. The ISS flight systems consist of Habitation; the Crew Health Care System (CHeCS); Extravehicular Activity (EVA); the Environmental Control and Life Support System (ECLSS); Computers and Data Management; Propulsion; Guidance, Navigation, and Control; Communications; the Thermal Control System (TCS); and the Electrical Power System (EPS). These flight systems provide a safe, livable, and comfortable environment in which crewmembers perform scientific research. Payloads, hardware, software, and crew support items on the ISS operate within the capabilities of these flight systems.

Integrated Truss Assembly

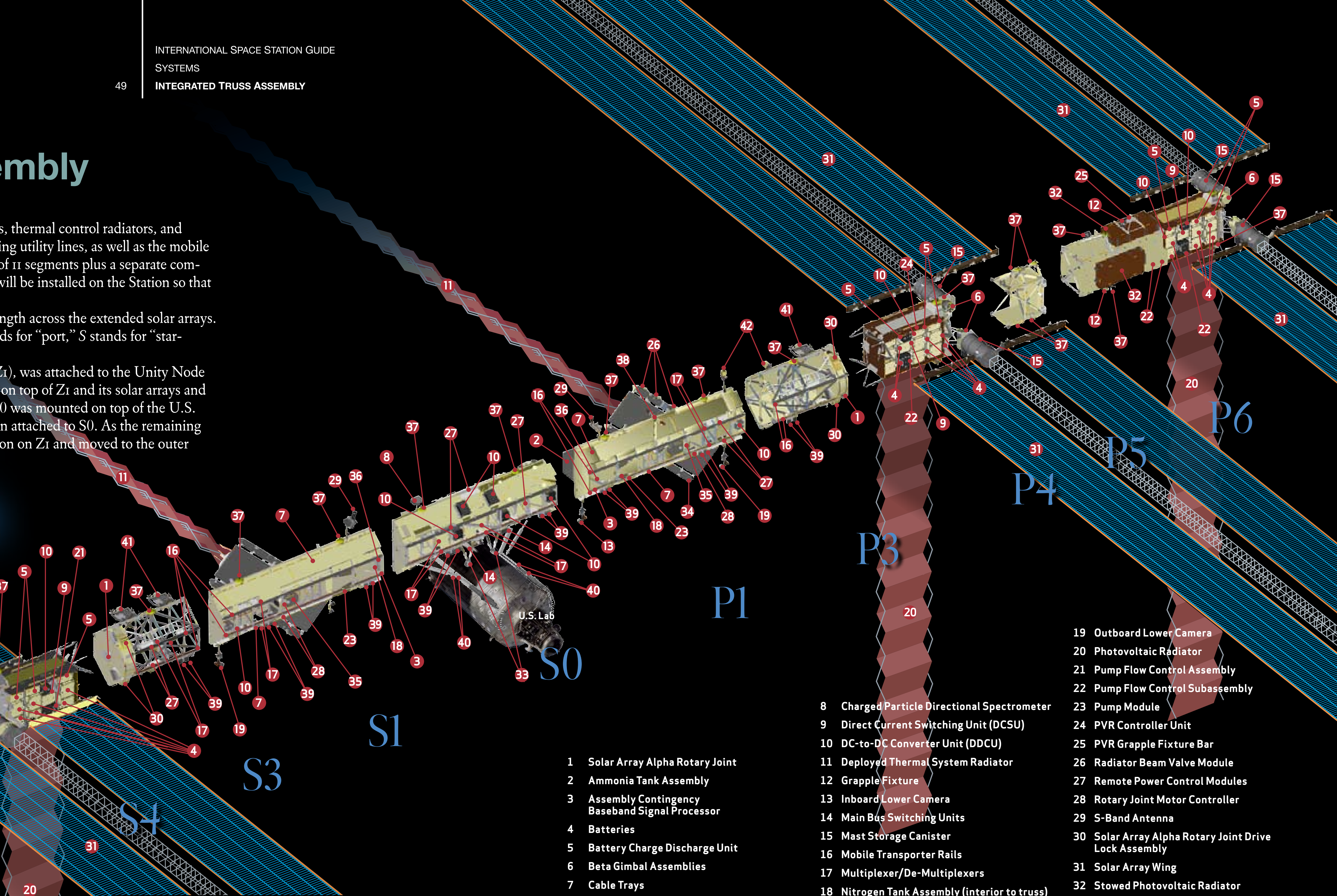
The truss assemblies provide attachment points for the solar arrays, thermal control radiators, and external payloads. Truss assemblies also contain electrical and cooling utility lines, as well as the mobile transporter rails. The Integrated Truss Structure (ITS) is made up of 11 segments plus a separate 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."

Initially, through Stage 8A, the first truss segment, Zenith 1 (Z1), was attached to the Unity Node zenith berthing mechanism. Then truss segment P6 was mounted on top of Z1 and its solar arrays and radiator panels deployed to support the early ISS. Subsequently, S0 was mounted on top of the U.S. Lab Destiny, and the horizontal truss members P1 and S1 were then attached to S0. As the remaining members of the truss are added, P6 will be removed from its location on Z1 and moved to the outer end of the port side.

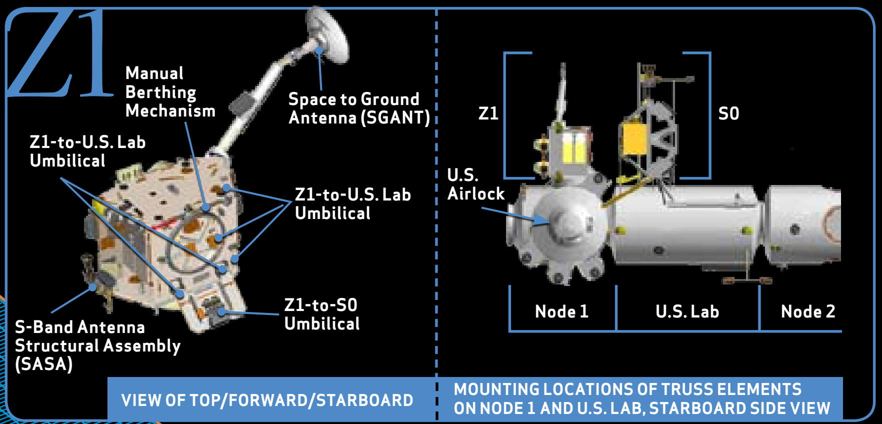


2003–06 configuration, looking from nadir.



2003–06 configuration, looking from aft.

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



Habitation

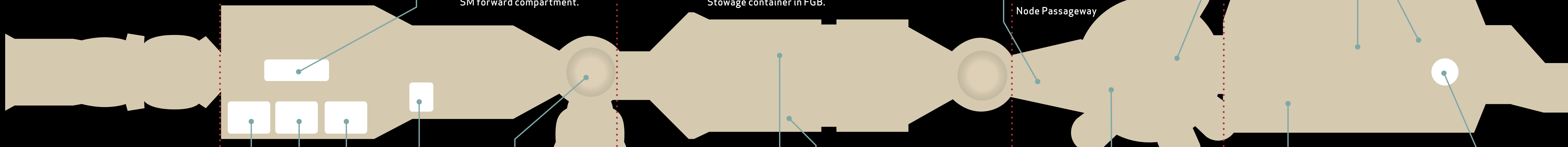
The habitable elements of the International Space Station are mainly a series of cylindrical modules. Many of the primary accommodations, including the waste management compartment and toilet, the galley, individual crew sleep compartments, and some of the exercise facilities, are in the Service Module (SM). A third sleep compartment is located in the U.S. Lab, and additional exercise equipment is in the U.S. Lab and the Node. Additional habitation capabilities for a crew of six will be provided prior to completion of ISS assembly.


Haircut in SM.


Shaving in SM.


Preparing meal in galley.


Playing keyboard in U.S. Lab.




SM mid compartment and treadmill.


SM forward compartment.


Stowage container in FGB.

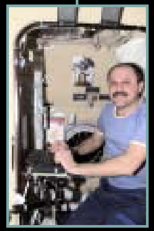

U.S./Joint Airlock


Node Passageway


U.S. Lab Computer Workstation


U.S. Lab Temporary Sleep Station (TSS)


Russian water containers.


SM Sleep Compartment


Remote Docking Control Station


SM Transfer Compartment


Stowed Food Trays in FGB


FGB Corridor and Stowage


Stowage in Node 1


Microgravity Science Glovebox in U.S. Lab


Toilet in Waste Management Compartment


Crewmembers Exercise on SM Treadmill


Crewmembers with Orlan Suits in Pirs


U.S. Lab Window

Crew Health Care System (CHeCS)/ Integrated Medical System

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

Countermeasures System (CMS)—The CMS provides the equipment and protocols for the performance of daily and alternative regimens (e.g., exercise) to mitigate the deconditioning effects of living in a microgravity environment. The CMS also monitors crewmembers during exercise regimens, reduces vibrations during the performance of these regimens, and makes periodic fitness evaluations possible.

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

Health Maintenance System (HMS)—The HMS provides in-flight life support and resuscitation, medical care, and health monitoring capabilities.


Leroy Chiao uses RED.


Crew uses medical restraint and defibrillator.

soyuz


Water Sampling and Analysis

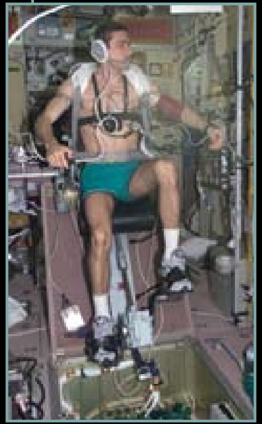
service module


Treadmill Vibration Isolation System (TVIS)


Blood Sample Reflotron


Saliva Sample Kit


CardioCog


Velo-Ergometer

fgb


Bonner Ball Neutron Particle Detector and Phantom Torso for radiation measurement experiments.

node/airlock


Resistive Exercise Device (RED)


Microbial Surface Sampling

u.s. lab

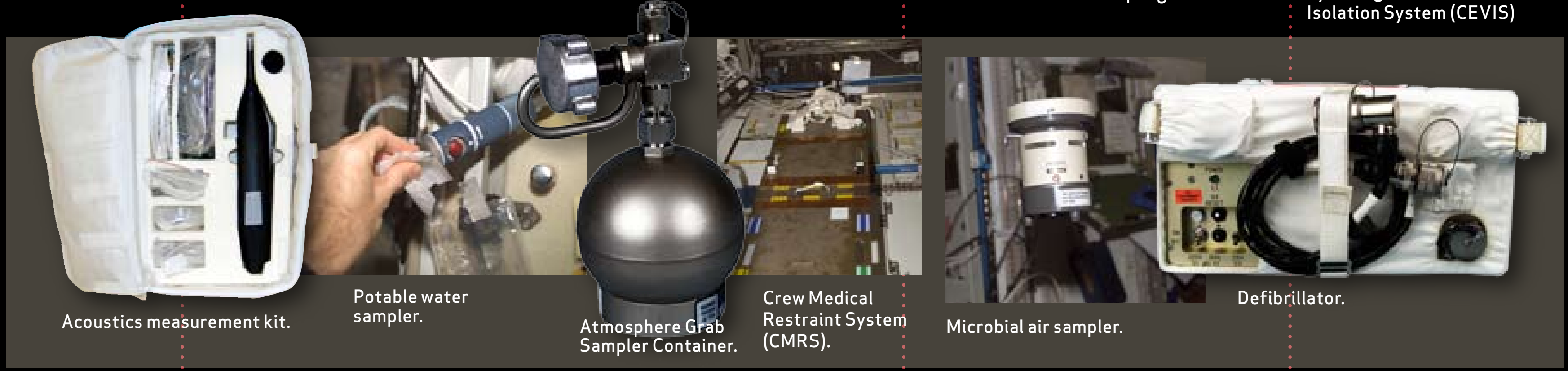

CHeCS Rack


Volatile Organics Analyzer (VOA)


Water Samples (taken for ground analysis of contamination)


Cycle Ergometer with Vibration Isolation System (CEVIS)


From left to right: Intravehicular Charged Particle Directional Spectrometer (IV-CPDS) (gold box) and Tissue Equivalent Proportional Counter (TEPC) detector (gold cylinder).


Acoustics measurement kit.

Potable water sampler.

Atmosphere Grab Sampler Container.

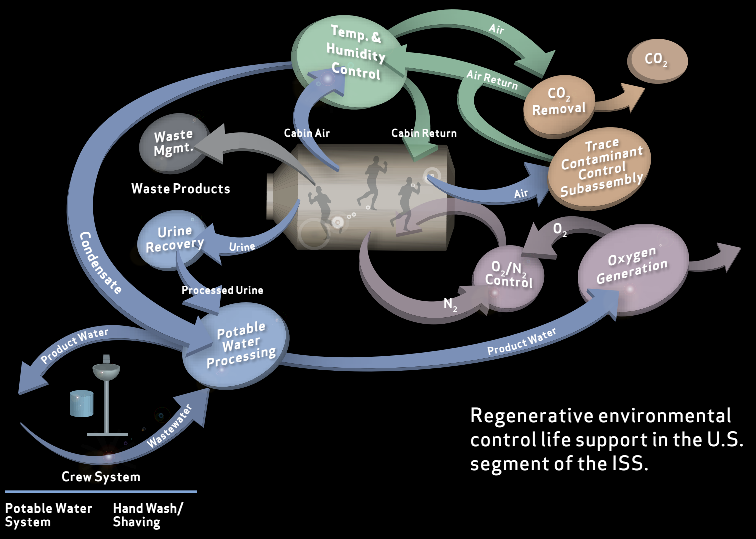
Crew Medical Restraint System (CMRS).

Microbial air sampler.

Defibrillator.

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.

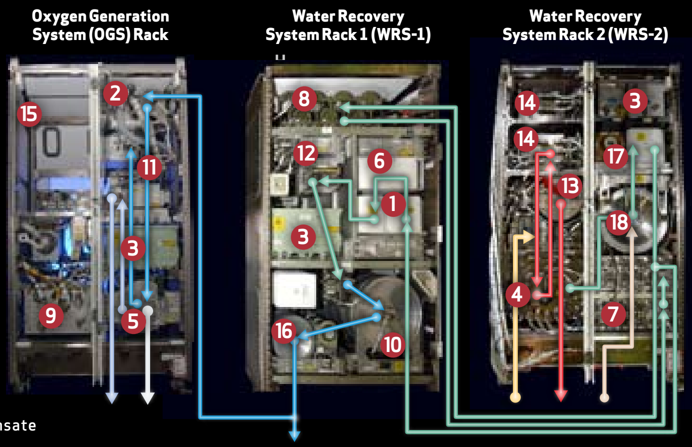


Regenerative environmental control life support in the U.S. segment of the ISS.

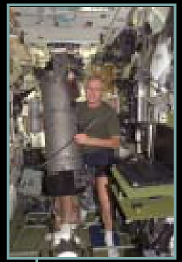
U.S. Regenerative Environmental Control and Life Support System (ECLSS)

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

🟦 = Oxygen
⬜ =Hydrogen (vented overboard)
🟦 =Potable Water
🟩 =Process Water
🟨 =Urine
🟥 =Brine
🟫 =Humidity Condensate



progress ········ service module ········ fgb ········ node/airlock ········ u.s. lab ········ shuttle



Elektron (produces oxygen from water through electrolysis; vents hydrogen out of the Station)

Vozdukh (absorbs carbon dioxide from crew)

Russian EDVs used to store and transport water.

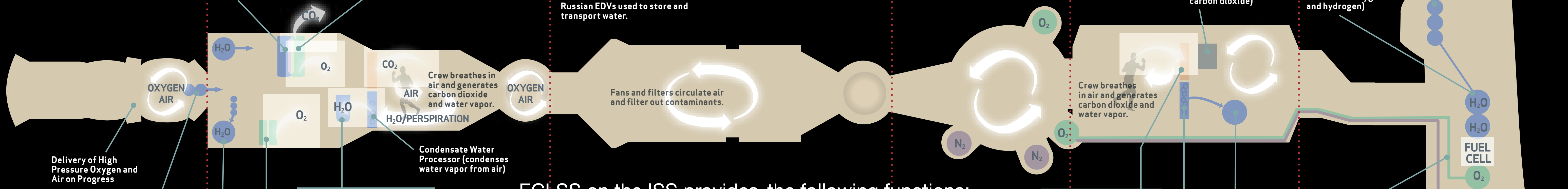
Lithium Hydroxide (LiOH) cartridge used for eliminating CO_2 from air, backup system.

Contingency Water Container (CWC) bag.

CWC Bags (used by astronauts to carry water from the Shuttle to the ISS)

Lithium Hydroxide Cartridges (absorb carbon dioxide)

Fuel Cells (make electricity and water from oxygen and hydrogen)



Crew breathes in air and generates carbon dioxide and water vapor.

Fans and filters circulate air and filter out contaminants.

Crew breathes in air and generates carbon dioxide and water vapor.

Delivery of High Pressure Oxygen and Air on Progress

Water Delivery from Progress

Freshwater Storage Tanks

Condensate Water Processor (condenses water vapor from air)

Lab Condensate Storage Tank (for condensate water)

Oxygen and Nitrogen (Shuttle replenishes the gases stored in the airlock tanks)

SM gas analyzer.

Airflow ventilation fan.

Russian EDVs (used to store reclaimed water)

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

ECLSS on the ISS provides the following functions:

- Recycle wastewater (including urine) to produce drinking (potable) water
- Store and distribute potable water
- Use recycled water to produce oxygen for the crew
- Remove carbon dioxide from the cabin air
- Filter the cabin air for particulates and microorganisms
- Remove volatile organic trace gases from the cabin air
- Monitor and control cabin air partial pressures of nitrogen, oxygen, carbon dioxide, methane, hydrogen, and water vapor
- Maintain total cabin pressure
- Detect and suppress fire
- Maintain cabin temperature and humidity levels
- Distribute cabin air between ISS modules (ventilation)

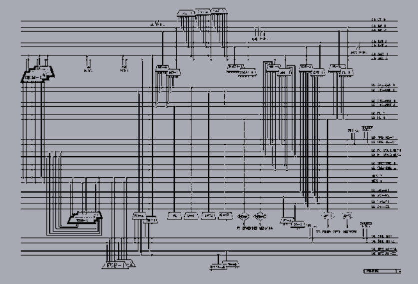
In the future, a new U.S. Regenerative Environmental Control and Life Support System will take additional steps toward closing the water cycle; it will take humidity condensate from the cabin air and urine from the crew and convert these into drinking water, oxygen for breathing, and hydrogen.

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

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

Computers and Data Management

The system for storing and transferring information essential to operating the ISS has been functioning at all stages of assembly. From a single module to a large complex of elements from many international partners, the system provides control of the ISS from either U.S., Russian, Canadian, and soon the European and Japanese segments of the ISS.



Data bus architecture consists of

- 100+ MIL-STD-1553B data buses,
- 60+ computers into which software can be loaded as necessary,
- 1,200+ remote terminals,
- 190 payload remote terminals,
- 600+ international partner and firmware controller devices, and
- 90+ unique types of remote devices.

SSRMS Control and Robotics Workstations

Laptop (in SM crew quarters)

Primary Command Workstation in SM

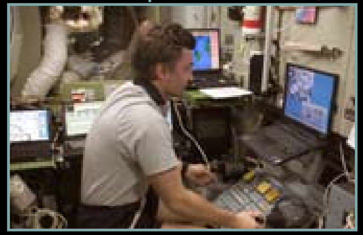
Crew uses Progress Remote Control workstation in SM

Maneuvering Truss Segments into Place at SSRMS Workstation

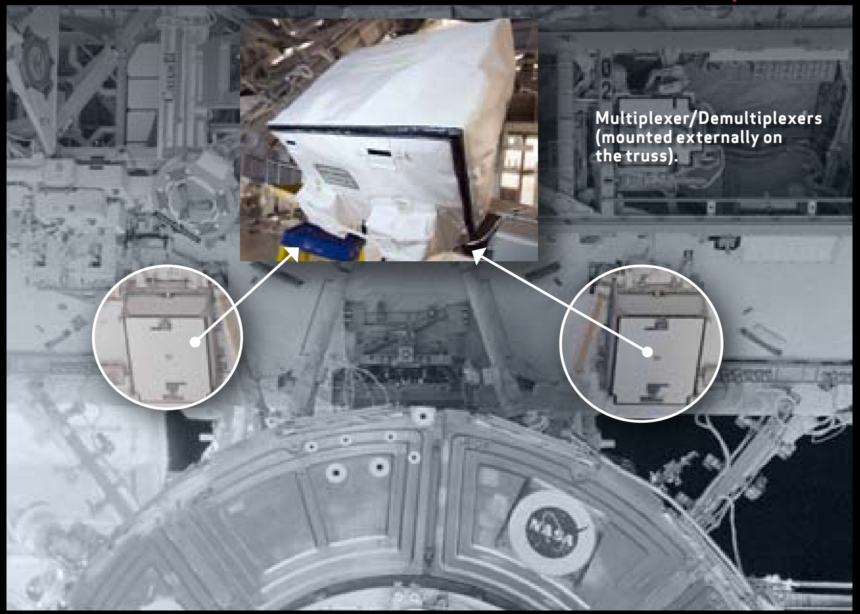
Multiplexer/Demultiplexer (computer)

Laptop and TVIS Control (located near galley)

Russian Segment Workstations

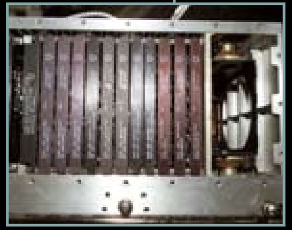


TORU Remote Progress Docking Workstation



Multiplexer/Demultiplexers (mounted externally on the truss).

Human Research Facility Workstation



Multiplexer/Demultiplexer Mass Memory Unit (MMU) Processor Data Cards in U.S. Lab

Propulsion

The ISS orbits Earth at an altitude that ranges from 370 to 460 kilometers (230 to 286 miles) and a speed of 28,000 kilometers per hour (17,500 miles per hour). Owing to atmospheric drag, the ISS is constantly slowed. Therefore, the ISS must be reboosted periodically in order to maintain its altitude. The ISS must sometimes be maneuvered in order to avoid debris in orbit. Furthermore, the ISS attitude control and maneuvering system can be used to assist in rendezvous and dockings with visiting vehicles, although that capability is not usually required.

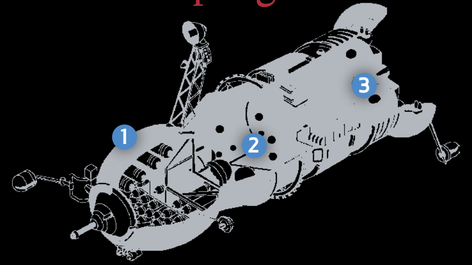
Although the ISS typically relies upon large gyrodynes, which utilize electrical power, to control its orientation (see “Guidance, Navigation, and Control”), when force that is beyond the production capability of the gyrodynes is required, rocket engines provide propulsion for reorientation.

Rocket engines are located on the Service Module, as well as on the Progress, Soyuz, and Space Shuttle spacecraft.

The Service Module provides 32 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.

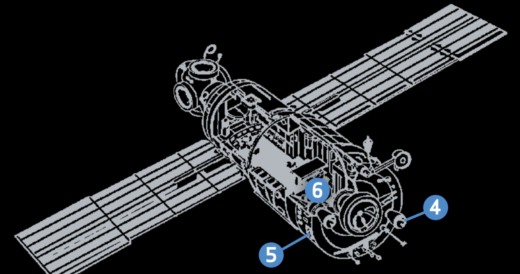
Besides being a resupply vehicle, the Progress provides a primary method for reboosting the ISS. Eight 13.3-kilograms force (29.3-pounds force) Progress engines can be used for reboosting. Engines on the Service Module, Soyuz vehicles, and Space Shuttle can also be used. The Progress can also be used to resupply propellants stored in the FGB that are used in the Service Module engines. The ESA ATV and JAXA HTV will also provide propulsion and reboost capability.

progress



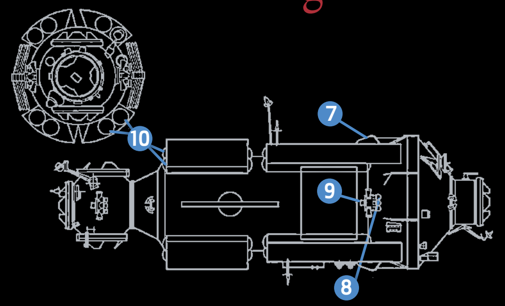
1 Progress Cargo Module
2 Propellant Resupply Tanks
3 Progress Propulsion System

service module



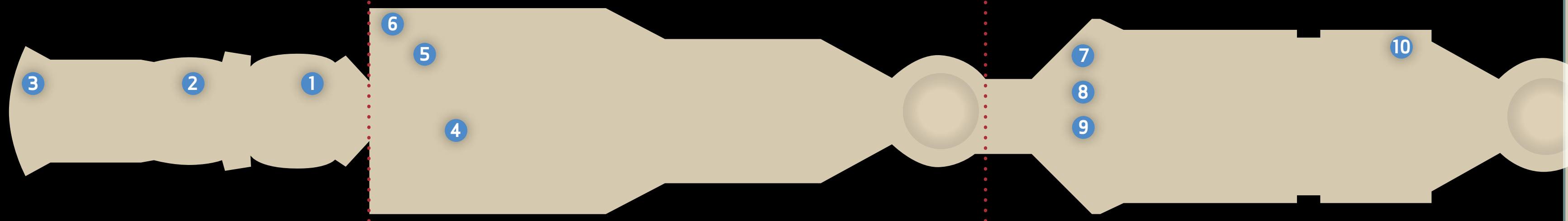
4 Main Engines (2)
5 Attitude Control Engines (32)
6 Propellant Tanks (4)

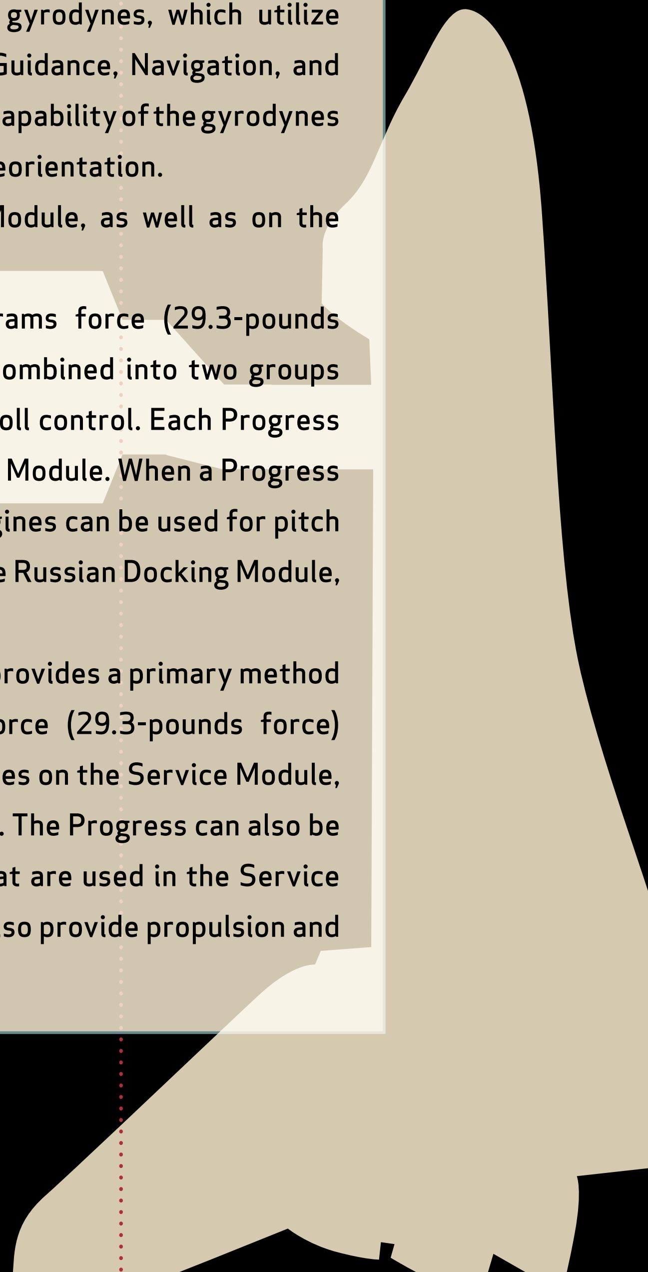
fgb



7 Correction and Docking Engines (2)
8 Docking and Stabilization Engines (24)
9 Accurate Stabilization Engines (16)
10 Propellant Tanks (16)

shuttle





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), lifetime of 25,000 seconds 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

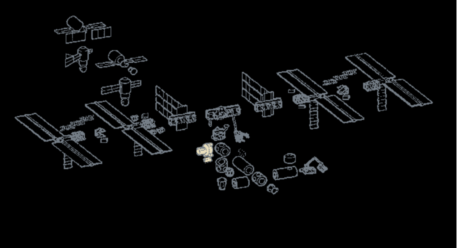
There are two types of propellant tanks in the Russian propulsion system: bellows tanks (SM, FGB), able both to receive and to deliver propellant, and diaphragm tanks (Progress), able only to deliver fuel.

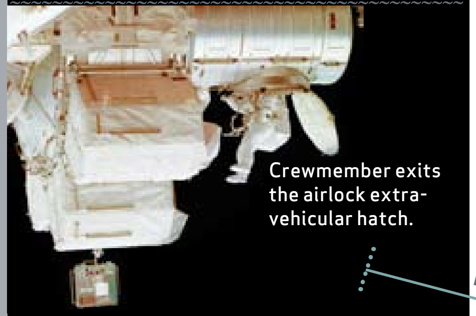
Sixteen tanks provide 5,760 kg (12,698 lb) of N_2O_4 and UDMH storage: eight long tanks, each holding 400 L (105.6 gal), and eight short tanks, each holding 330 L (87.17 gal).

Extravehicular Activity (EVA)

To date, there have been more than 69 EVAs (operations outside of the ISS pressurized modules) from the ISS totaling some 400 hours. Approximately 124 spacewalks, totaling over 900 hours, dedicated to assembly and maintenance of the Station will have been accomplished by Assembly Complete. Most of these EVAs have been for assembly tasks, but many were for maintenance, repairs, and science. These tasks were conducted from three different airlocks—the Shuttle Airlock, the U.S. Quest Airlock, and the Russian Pirs. Early in the program, an EVA was conducted from the Service Module Transfer Compartment. EVAs are conducted using two different spacesuit designs, the U.S. Extravehicular Mobility Unit (EMU) and the Russian Orlan.

The operational lessons of the ISS in the areas of EVA suit maintainability, training, and EVA support may prove critical for long-duration crewed missions that venture even further from Earth.



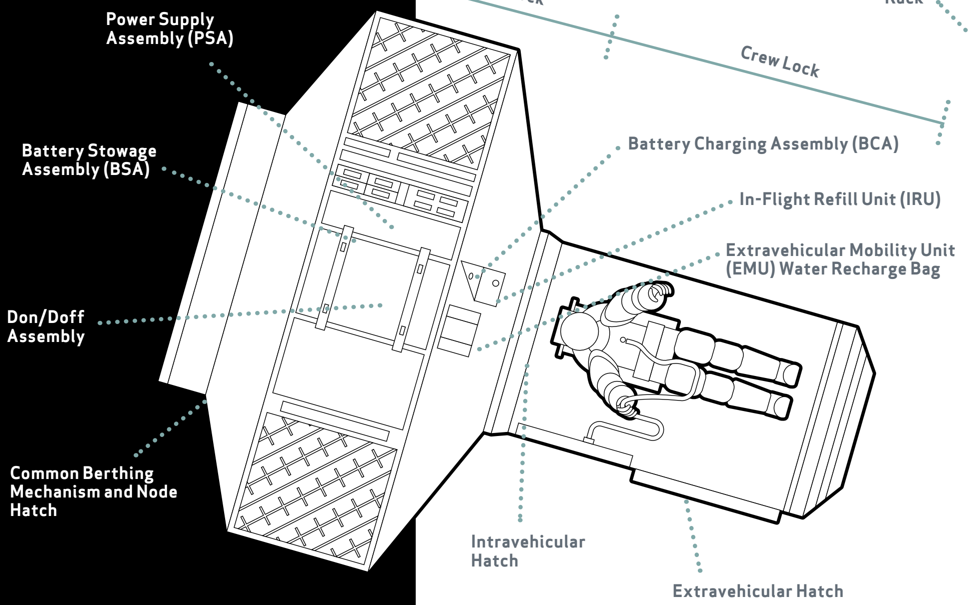


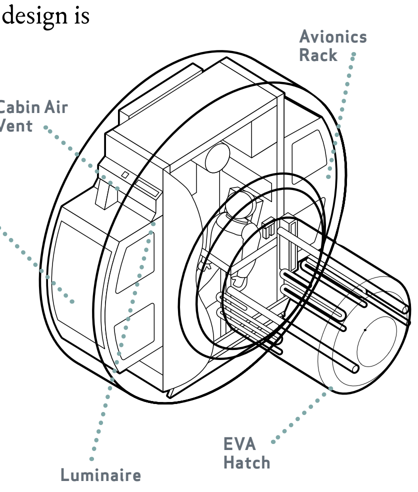
Crewmember exits the airlock extra-vehicular hatch.

U.S./Joint Airlock (Quest)

NASA/Boeing

The Quest airlock provides the capability for extravehicular activity (EVA) using the U.S. Extravehicular Mobility Unit (EMU). The airlock consists of two compartments: 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 Crew Lock design is based on the Space Shuttle's airlock design.

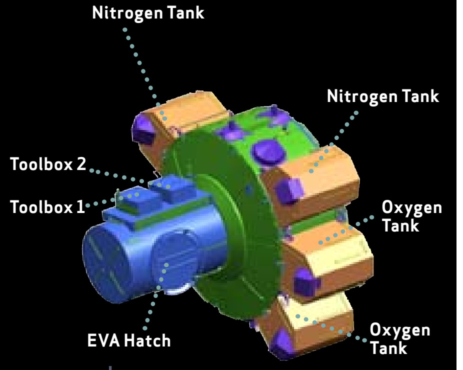




Mike Fincke, flight engineer on Expedition 9, inside Quest's Equipment Lock.

Space Shuttle mission STS-104 berths Quest to the starboard side of Node 1 in July 2001.

Airlock in preparation for launch in the Space Station Processing Facility at Kennedy Space Center.

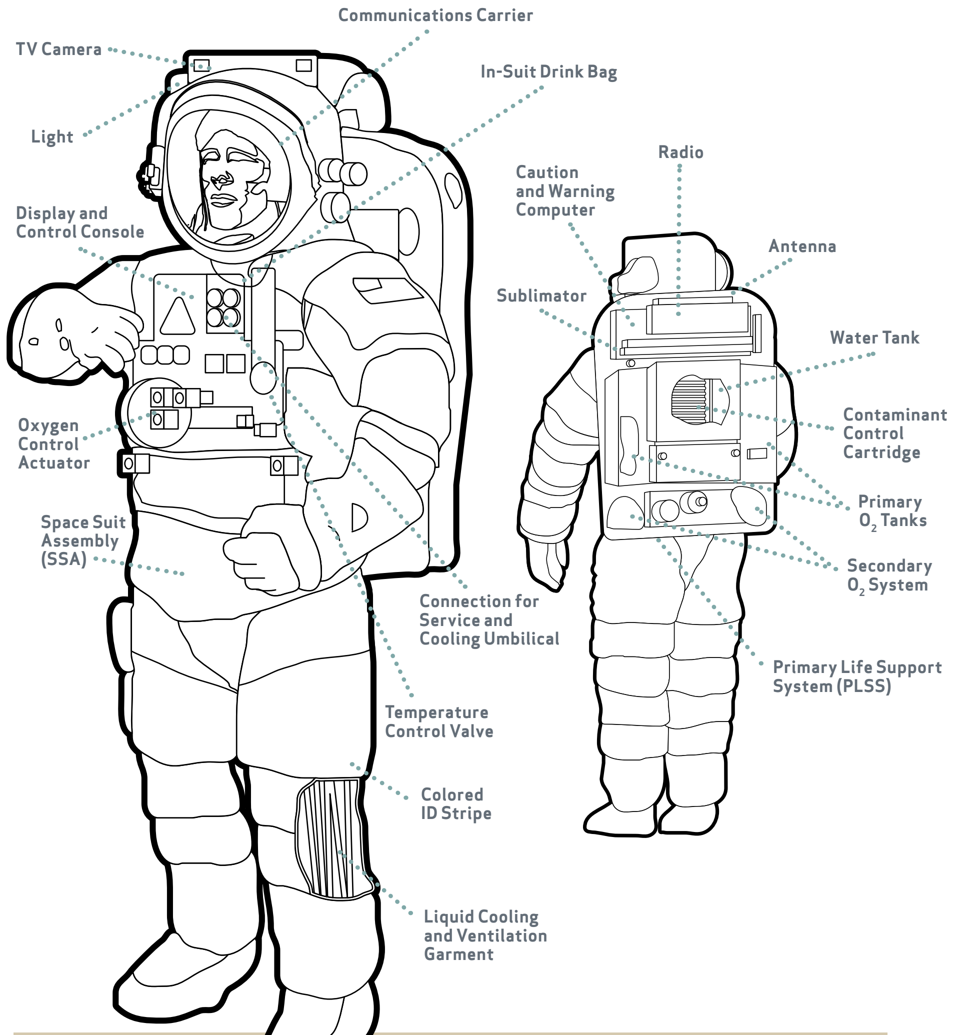


Length	5.5 m (18 ft)
Width	4.0 m (13.1 ft)
Mass	9,923 kg (21,877 lb)
Launch date	July 2001, on STS-104, ISS flight 7A. The Shuttle berthed to the starboard side of Node 1.

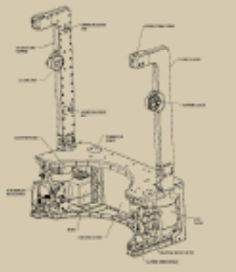
Extravehicular Mobility Unit (EMU)

NASA/Hamilton Sundstrand/ILC Dover

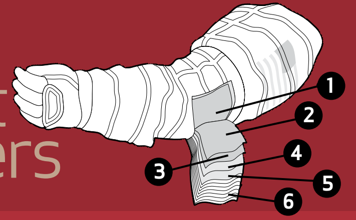
The EMU provides a crewmember with life support and an enclosure that enables EVA. The unit consists of two major subsystems: the Life Support Subsystem (LSS) and the Space Suit Assembly (SSA). The EMU provides atmospheric containment, thermal insulation, cooling, solar radiation protection, and micrometeoroid/orbital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



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.



Suit Layers



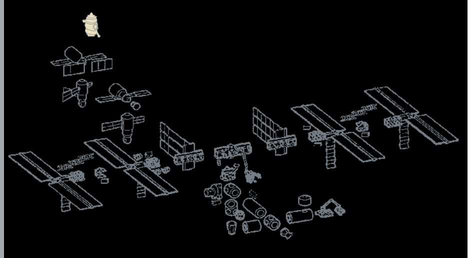
1 Thermal Micrometeoroid Garment (TMG). Cover: Ortho/KEVLAR® reinforced with GORE-TEX®.
2 TMG Insulation. Five to seven layers of aluminized Mylar® (more layers on arms and legs).
3 TMG liner. Neoprene-coated nylon ripstop.
4 Pressure garment cover. Restraint: Dacron®.
5 Pressure garment bladder. Urethane-coated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

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	178 kg (393 lb)
Suit life	30 yr

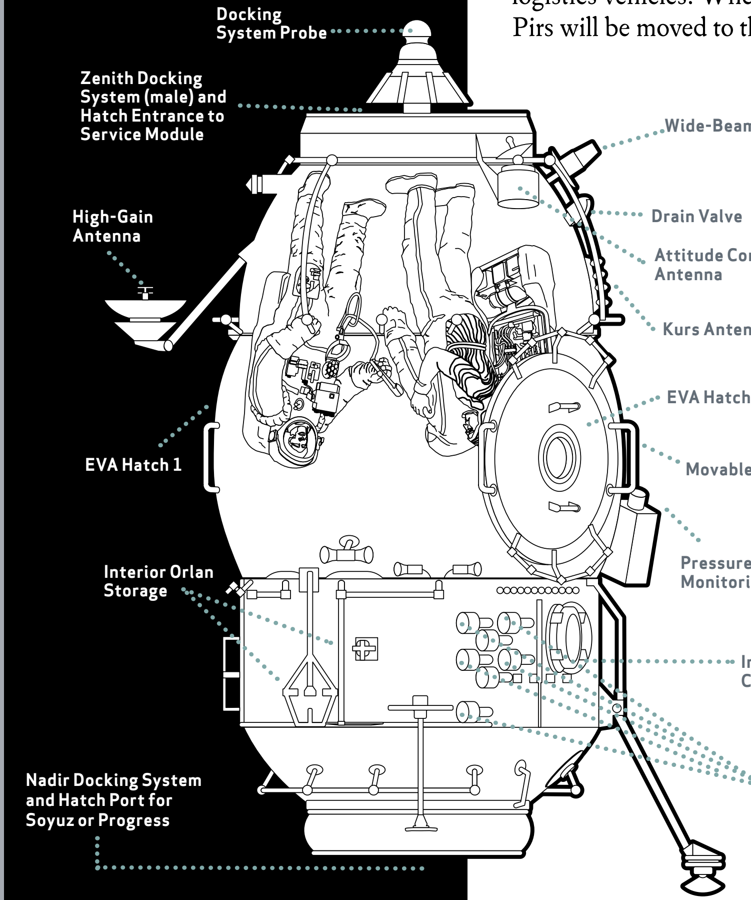
Russian Docking Compartment (DC) and Airlock (Pirs [Pier])

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

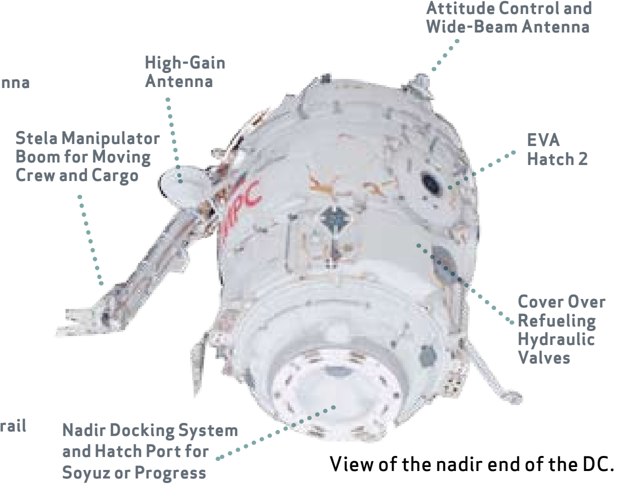
Pirs provides the capability for extravehicular activity using Russian Orlan suits. Pirs also provides contingency capability for ingress for U.S. EMU EVAs. Additionally, Pirs provides systems for servicing and refurbishing the Orlan suits. The nadir Docking System on Pirs provides a port for the docking of Soyuz and Progress logistics vehicles. When the final Russian science module arrives, Pirs will be moved to the zenith Service Module port.



View of the zenith end of the DC, with probe extended, as it prepares to dock with the ISS in 2001.



Length	4.9 m (16 ft)
Maximum diameter	2.55 m (8.4 ft)
Mass	3,838 kg (8,461 lb)
Volume	13 m^3 (459 ft^3)
Launch date	August 14, 2001, on Progress M, ISS mission 4R



View of the nadir end of the DC.

DC in preparation for launch.

Inside Pirs, the crew prepares Orlan suits for EVA.

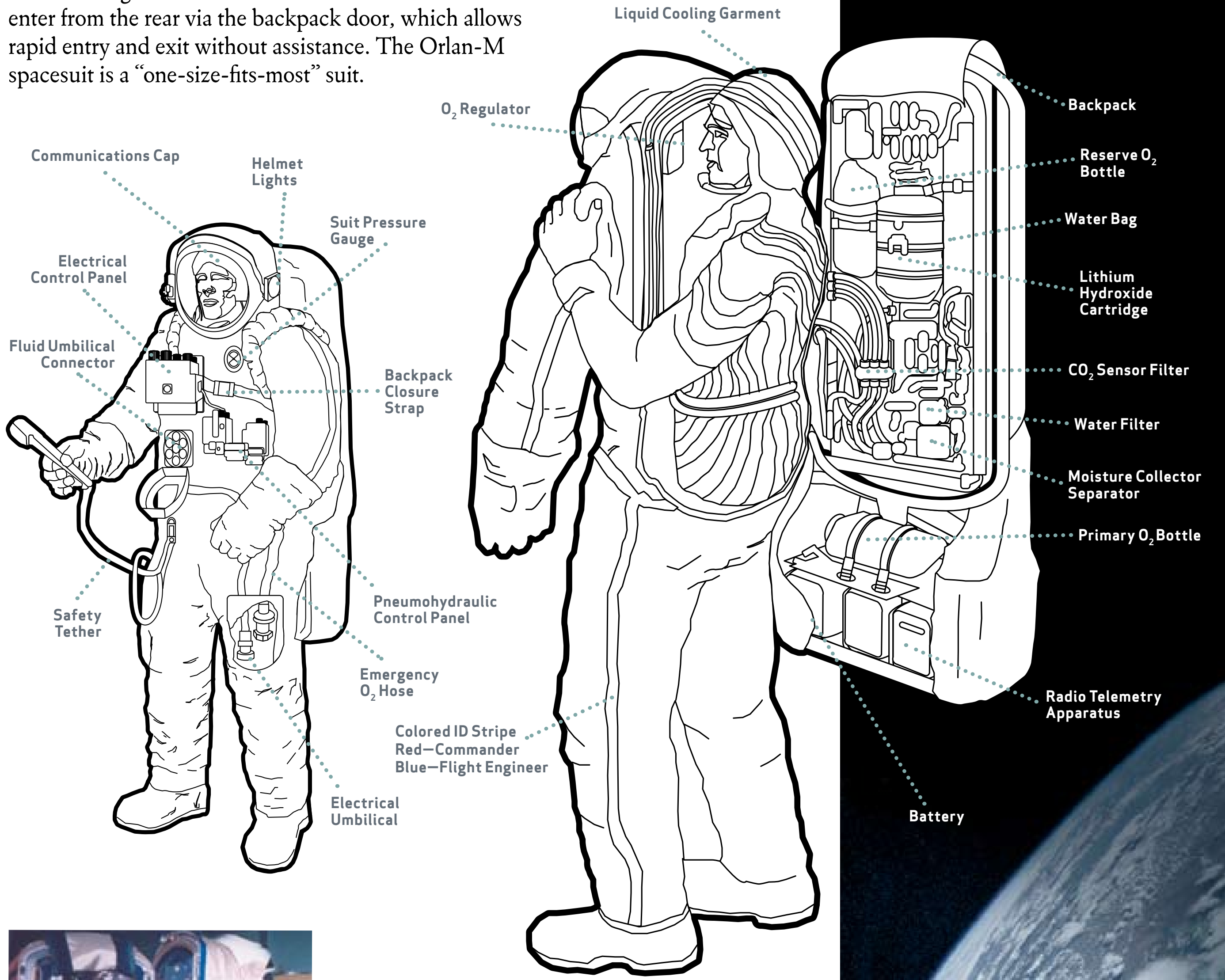
Pirs Module location at Service Module nadir.

Orlan Spacesuit

Science Production Enterprise Zvezda

The Orlan-M spacesuit is designed to protect an EVA 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-M spacesuit is a “one-size-fits-most” suit.

Crewmember in liquid cooling garment prepares to enter Orlan hatch.



Interior of Orlan suit with rear access hatch open.

The suit operates at a nominal 0.4 atm (5.8 psi) with a 100% oxygen atmosphere.

The suit’s maximum EVA duration is 7 hours.

The weight of the entire Orlan assembly is 238 lb.

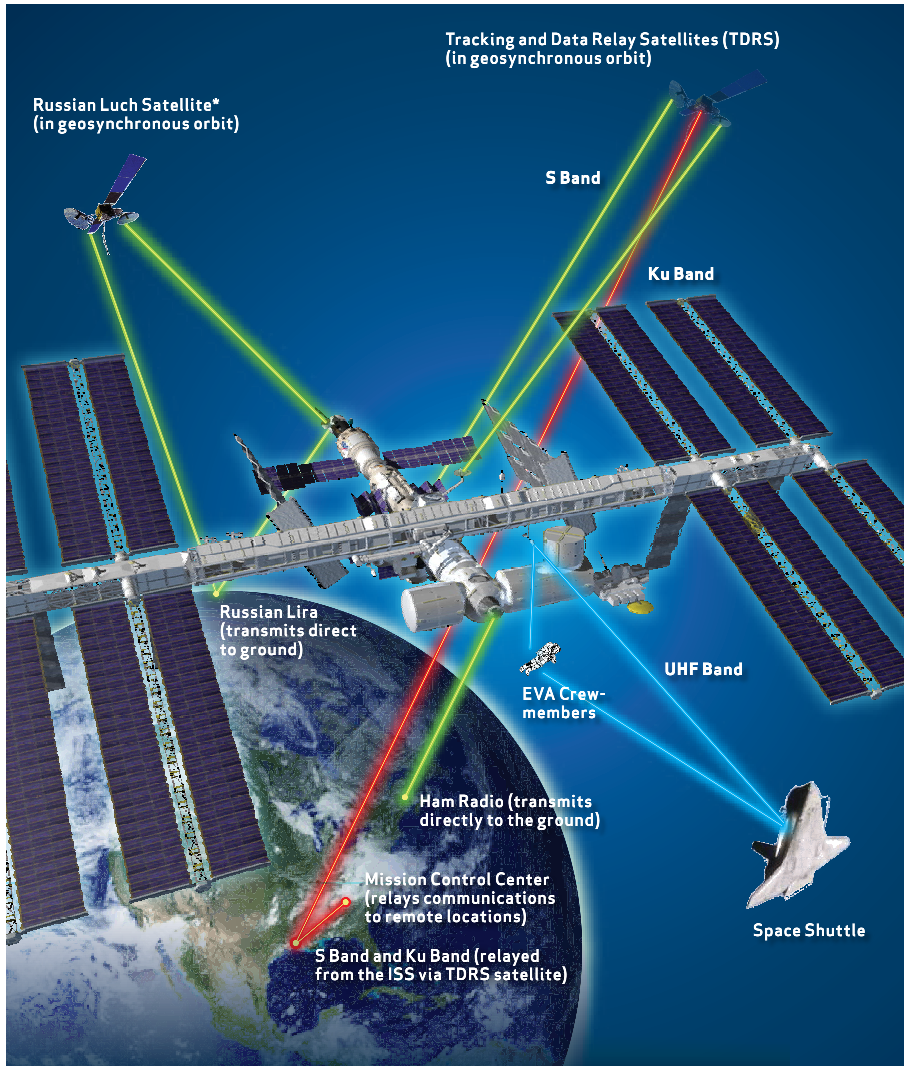
Orlan is designed for an on-orbit lifetime of 12 EVAs or 4 years without return to Earth.

Communications

The radio and satellite communications network allows ISS crews to talk to the ground control centers and the orbiter. It also enables ground control to monitor and maintain ISS systems and operate payloads, and it permits flight controllers to send commands to those systems. The network routes payload data to the different control centers around the world.

The communications system provides the following:

- Two-way audio and video communication among crewmembers aboard the ISS, including crewmembers who participate in an extravehicular activity (EVA);
- Two-way audio, video, and file transfer communication between the ISS and flight control teams located in the Mission Control Center-Houston (MCC-H), other ground control centers, and payload scientists on the ground;
- Transmission of system and payload telemetry from the ISS to the MCC-H and the Payload Operations Center (POC);
- Distribution of ISS experiment data through the POC to payload scientists; and
- Control of the ISS by flight controllers through commands sent via the MCC-H.



*Luch not currently in use.


Ku band radio in U.S. Lab.


UHF antenna on the P1 Truss.


ISS configuration, 2003–2006.


Yuri Onofrienko during communications pass.

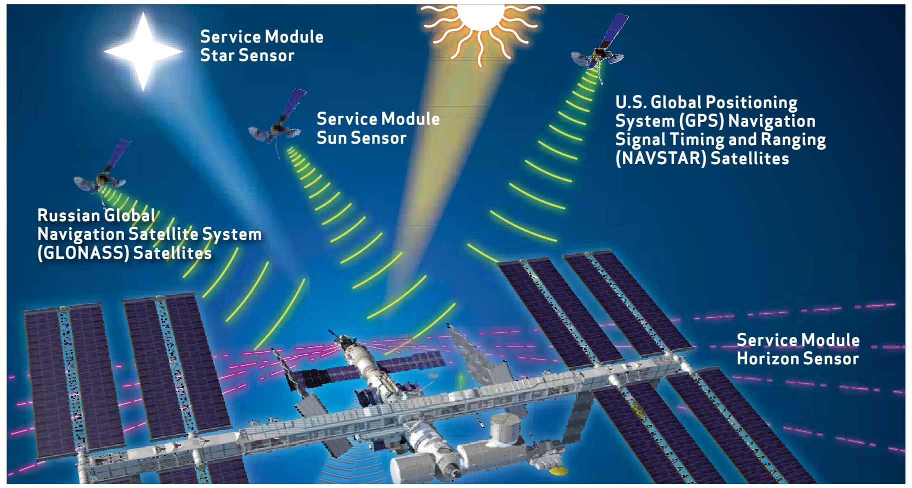

Tammy Jernigan wearing EMU communications carrier ("Snoopy cap").

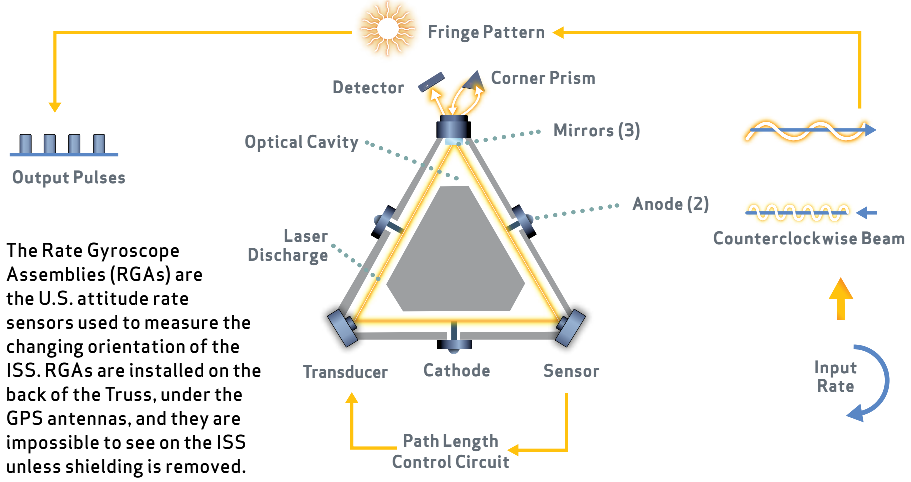
Guidance, Navigation, and Control (GN&C)

The International Space Station 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.

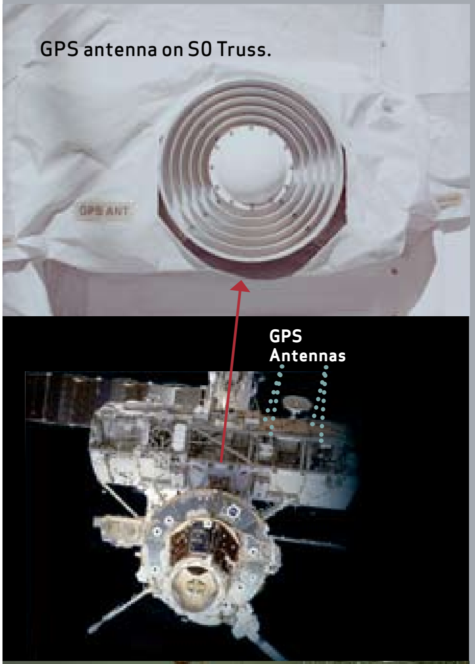
The GN&C system tracks the Sun, communications and navigation satellites, and ground stations. Solar arrays, thermal radiators, and communications antennas aboard the ISS are pointed using the tracking information.

The preferred method of attitude control is the use of gyrodynes, Control Moment Gyroscopes (CMGs) mounted on the Z1 Truss segment. CMGs are 98-kilogram (220-pound) steel wheels that spin at 6,600 revolutions per minute (rpm). The high-rotation velocity and large mass allow a considerable amount of angular momentum to be stored. Each CMG has gimbals and can be repositioned to any attitude. As the CMG is repositioned, the resulting force causes the ISS to move. Using multiple CMGs permits the ISS to be moved to new positions 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, rocket engines are called upon.



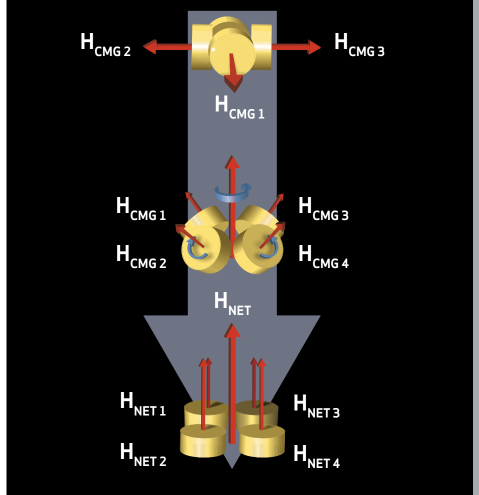


The Rate Gyroscope Assemblies (RGAs) are the U.S. attitude rate sensors used to measure the changing orientation of the ISS. RGAs are installed on the back of the Truss, under the GPS antennas, and they are impossible to see on the ISS unless shielding is removed.

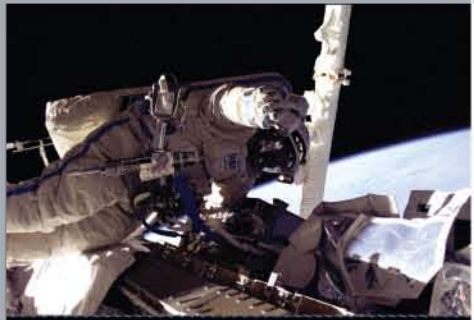

GPS antenna on S0 Truss.


Control Moment Gyroscopes on the Z1 Truss.


Control Moment Gyroscope gimbals used for orienting the ISS.



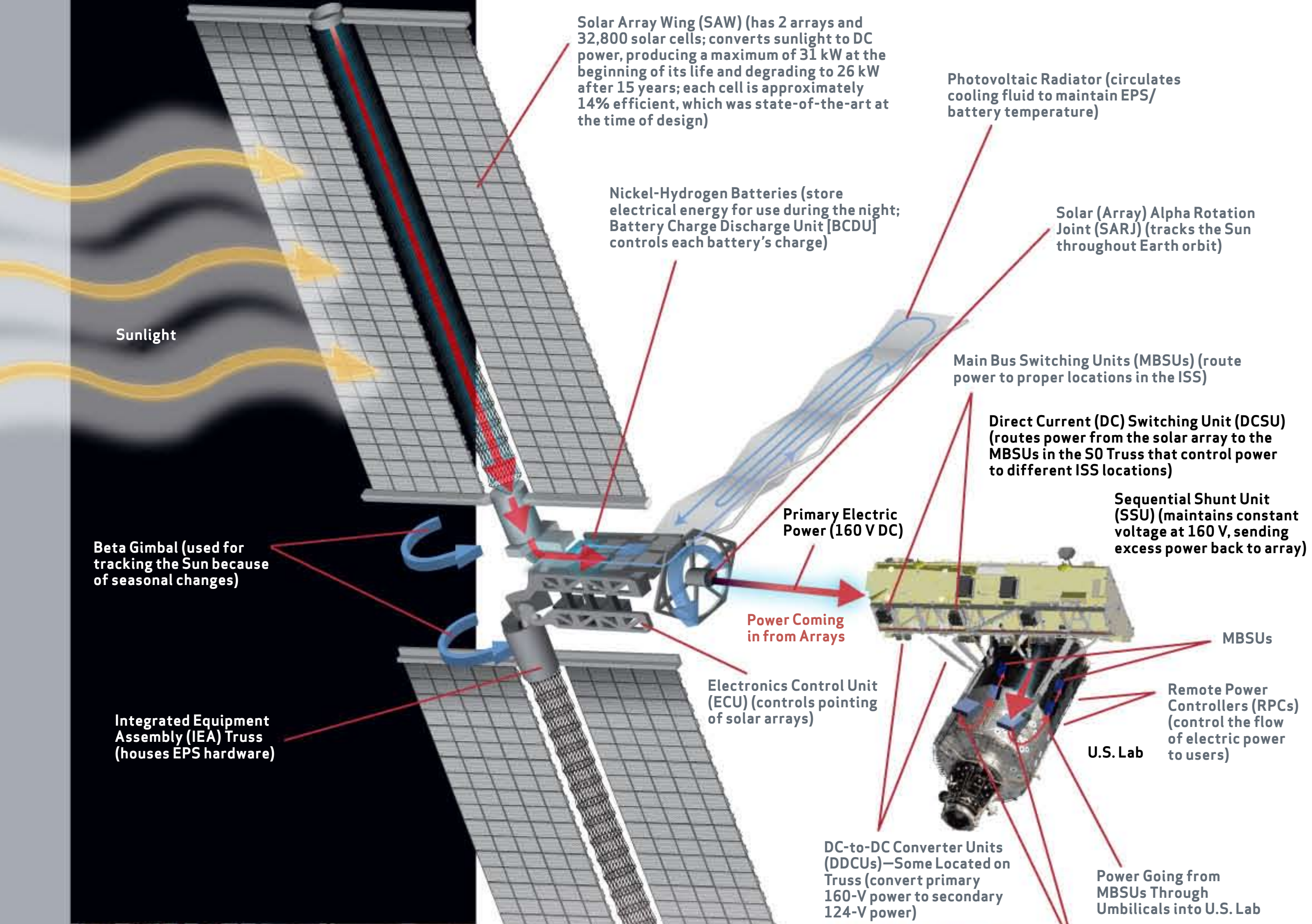
Forces are induced as CMGs are repositioned.



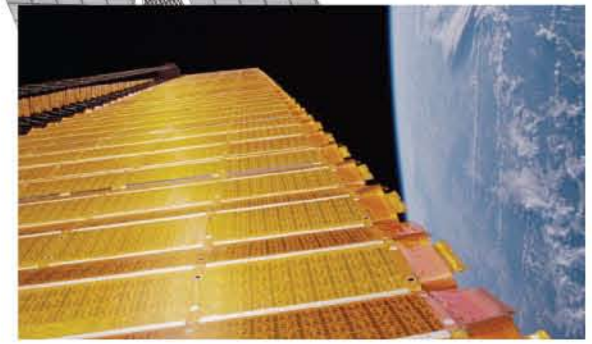
Crewmember Mike Fincke replaces the Remote Power Controller Module (RPCM) on the S0 Truss.

Electrical Power System (EPS)

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



Crewmember Mike Fincke holds an RPCM in the Quest Airlock. It was later used to replace an RPCM on the S0 Truss.



Solar Array.

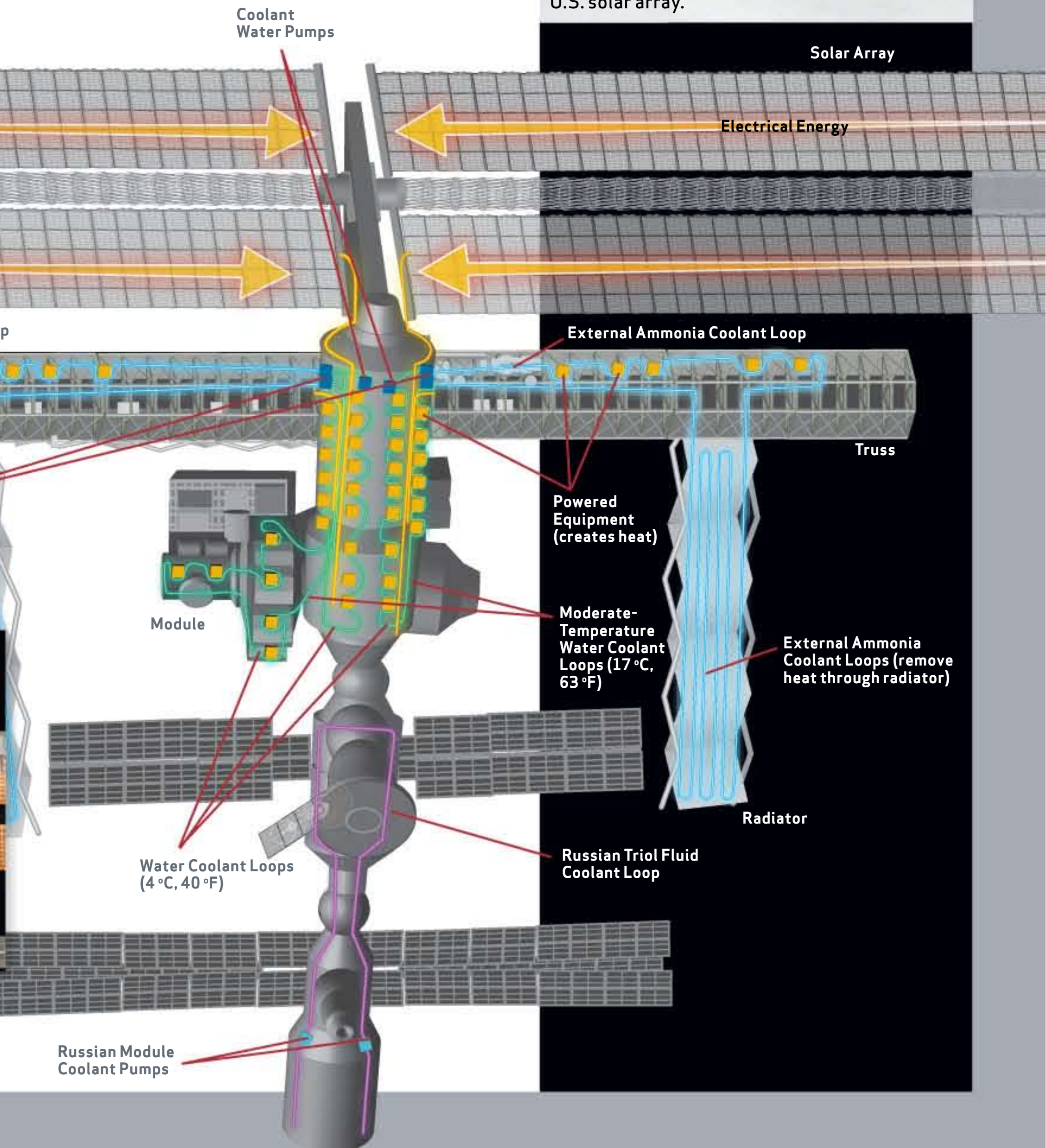
Thermal Control System (TCS)

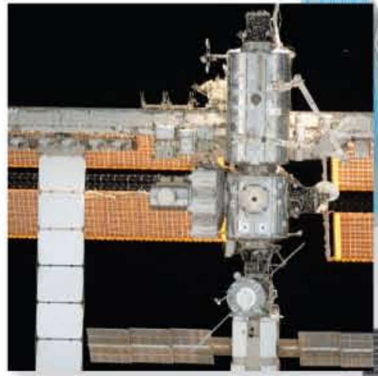
The TCS maintains ISS temperatures within defined limits. The four components used in the Passive Thermal Control System (PTCS) are insulation, surface coatings, heaters, and heat pipes.

The Active Thermal Control System (ATCS) is required when the environment or the heat loads exceed the capabilities of the PTCS. The ATCS uses a mechanically pumped fluid in closed-loop circuits to perform three functions: heat collection, heat transportation, and heat rejection.

Inside the habitable modules, the internal ATCS uses circulating water to transport heat and cool equipment. Outside the habitable modules, the external ATCS uses circulating ammonia to transport heat and cool equipment.

Port and Starboard Radiator panels from truss below U.S. solar array.





Starboard radiator panel after deployment.

MCC Houston